THE
GEOLOGICAL MAGAZINE
VOLUME LX.

No. IV.—APRIL, 1923.

EDITORIAL NOTES.

THE list of the names of those recommended by the Council for election to the Royal Society appeared just too late for inclusion in the March number of the MAGAZINE. The only name of immediate interest to our readers is that of Sir Douglas Mawson, the well-known Australian geologist and Antarctic explorer.

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AT the Annual General Meeting of the Geological Society of London, held on 16th February, after the usual presentation of the medals and awards to the recipients, whose names have already been recorded here, Professor Seward proceeded to deliver his presidential address, giving first the usual obituary notices of deceased Foreign Members, Foreign Correspondents, and Fellows. The chief subject of the Address was "The Earlier Records of Plant Life". The first part comprised a discussion of the physical conditions of the Pre-Cambrian periods, with a review of indirect evidence for the existence of plant life. Palæobotanical records from the Lower Palæozoic were then briefly summarized. The second part of the address dealt in some detail with the floras of the Devonian and Old Red Sandstone.

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A COMMITTEE has been formed to carry through a memorial to the late Mr. Benjamin Harrison, the well-known geologist and pre-historic anthropologist of Ightham, Kent. Two suggestions are under consideration: (1) the foundation of a scholarship open to natives of Ightham and district, or failing this, of Kent or of some even wider area; (2) a research fund. It is also proposed to place a tablet in Ightham Parish Church. Donations may be sent to the Hon. Secretary and Treasurer, Mr. de Barri Crawshay, Rosefield, Sevenoaks, Kent.

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THE Geological Society of London has lately been the recipient of a benefaction to be called "The Gloyne Outdoor Geological Research Fund". Its object is to promote field research by enabling the Council to make grants in aid to suitable applicants. The Council, in a circular recently issued calls special attention to the fact that the testator expressly spoke of his benefaction as the *nucleus* of a fund, and it ventures to hope that others may feel impelled to copy his excellent example.

ORIGINAL ARTICLES.

Tarsophlebiopsis mayi n.g. et n.sp., a Dragon-fly, found in the body-chamber of a Corallian Ammonite.

By R. J. Tillyard, M.A., Sc.D. (Cantab.), D.Sc. (Sydney), C.M.Z.S., F.L.S., F.E.S., Entomologist and Chief of the Biological Department, Cawthron Institute, Nelson, N.Z.

(PLATE IV.)

THE remarkable specimen dealt with in this paper was discovered by Mr. R. May, of Downing College, Cambridge, in the earlier part of the year 1922, and was forwarded to me by Mr. Henry Woods, F.R.S., for study and description. Mr. Woods informs me that " the specimen was found in the Boulder Clay of Hertfordshire, and consists of a portion of a body-chamber of a Perisphinctoid Ammonite in the matrix of which there are wings of a dragon-fly. The ammonite is, of course, derived. It has been examined by Dr. L. F. Spath, Dr. F. L. Kitchin, and Mr. J. Pringle, each of whom has stated that he believes it has come from the Ampthill Clay (of Corallian age) ".

There are three fragments of a dragon-fly's wings, all embedded in the matrix of the body-chamber of the ammonite. The fragment (Pl. IV, Fig. 1) consists of the basal half of the right fore-wing, the impression lying right side up, with the radius convex and the subcosta concave. An even larger fragment (Pl. IV, Fig. 2) consists of the greater portion of the distal two-thirds of a hind-wing of the same insect as that represented by the former fragment ; but in this case the wing is the left wing, the impression being upside down, with the radius concave and the media convex. A third, much smaller fragment (not figured) consists only of the basal posterior margin of a hind-wing, with the two rows of cellules above it in the anal or " postcostal " field. This fragment also appears to be impressed upside down, and must therefore be a portion of the base of the same wing, as Fig. 2 in Pl. IV, torn away from it and drifted into a position about 40 mm. away from the main part of the wing.

All three fragments clearly belong to one and the same insect, and must have been washed into the body-chamber of the dead ammonite with the deposit which now forms its hardened matrix. That is to say, the geological age of the dragon-fly is the same as that of the ammonite, though in point of actual time it may be assumed that the ammonite died first, and decomposed, and then the dragon-fly died and was washed away, its remains coming to rest within the body-chamber of the dead ammonite while it was being filled up by a muddy deposit. Thus the conditions of fossilization of the insect somewhat resemble those under which the Solenhofen and Eichstätt dragon-flies were preserved in the Upper Jurassic of Bavaria ; but, in the present case, the remains of the dragon-fly found a resting-place which I think must be quite unique in the whole record of fossil insects.

The impression of the fore-wing is clear, and of the same colour as the matrix. The two fragments of the hind-wing, on the other hand, have left impressions which are deeply pigmented. A possible explanation of this may be that the dragon-fly had hyaline fore-wings and deeply coloured hind-wings, just like the well-known *Neurobasis chinensis* (L.) of the present day. It certainly belonged to a family which had the slender grace and general build of the Calopteryginæ, though the venation differed from that of these modern brightly coloured insects in a number of important respects.

There is no difficulty in assigning the fossil to the family Tarsophlebiidæ, owing to the extraordinary formation of the incomplete arculus, combined with the long, complete series of unspecialized antenodals. Handlirsch (1908) gives, for this family, only a single genus, *Tarsophlebia* Hagen, represented by four species, three of which occur in the Lithographic Limestone of Eichstätt, Bavaria (Upper Jurassic, Malm) and one in the Lower Lias of Cheltenham, England. Having recently studied the whole of the Liassic Odonate material in the British Museum, I am convinced that the fragment of a wing named *Tarsophlebia westwoodi* by Giebel, from the Lower Lias of Cheltenham, is not a *Tarsophlebia* at all, but belongs to an entirely distinct family, confined to the Lower Lias, which I intend to call Liassophlebiidæ. The two families agree only in the incompleteness of the arculus-formation, but differ greatly in general build and venation, and particularly in the number and form of the antenodals, of which the Liassophlebiidæ have only two very strongly hypertrophied ones, whereas the Tarsophlebiidæ have a complete series of unspecialized antenodals.

Thus we see that the family Tarsophlebiidæ is confined as far as present knowledge goes to the Upper Jurassic (Malm) of Bavaria. The discovery of the fossil dealt with in this paper constitutes the first record of the family for England; for the Upper Jurassic material recently examined by me from the British Museum does not contain a single representative of this family, or any close relative of it.

It is clear, then, that the age of the fossil is undoubtedly Upper Jurassic. By comparison with the genus *Tarsophlebia*, the new type can be shown to be somewhat more specialized, notably by the presence of the oblique continuation of the distal side of the open discoidal cell, forming the basal portion of Cu_2, and also by the secondary reticulation of the median and submedian spaces; these areas are free from excess cross-veins both in the genus *Tarsophlebia* and also in all known Liassic types of Odonata. This, however, does not prove that the new fossil is actually of later date, geologically, than its close relative; for, in all families of insects at the present day, different genera show conditions of greater or less specialization by comparison with related forms. One can say, with fair certainty, that the fossil belongs to a horizon older than the Purbeck beds, for the Odonata of those beds are fairly well known,

and consist definitely of types which are more specialized than the Tarsophlebiidæ. The horizon of the fossil may be placed somewhere in the Middle Oolite or the lower part of the Upper Oolite, no evidence deducible from the venational structure of the wing can place it more definitely than that. This conclusion agrees well enough with that of the experts who have examined the Ammonite, for they all agree that it comes from the Corallian, i.e. the uppermost beds of the Middle Oolite.

It remains for me, before proceeding to give a detailed description of the fossil, to thank my friend Mr. Henry Woods for affording me the opportunity of studying and describing this unique fossil. Now that it is known that insect remains occur in the Corallian beds, it may be hoped that further search may reveal a little more of the Odonate fauna of that time, though, judging by our knowledge of the beds of the Bavarian Upper Jurassic, there can be little doubt that such discoveries will only be very few and far between. My thanks are also due to Mr. W. C. Davies, Curator of the Cawthron Institute, for the excellent photographs from which Plate IV has been prepared.

Order **ODONATA.**

Sub-order *ANISOZYGOPTERA.*

Family TARSOPHLEBIIDÆ.

Handlirsch (1908) places the family in the Sub-order Anisozygoptera, on account of the obvious difference in the size of the fore- and hind-wings, the latter being shorter than the former and wider at its base; the anal or "postcostal" field of the fore-wing is narrow, carrying only a single row of cellules, while that of the hind is much broader basally, with two rows of cellules.

The family is recognized at once by the following characters: Insects of moderate size and of very slender, delicate build, the legs and abdomen long and slender. Wings with a long series of unspecialized antenodals, the nodus being placed near the middle of the wing-length. Pterostigma present, elongated. Arculus incomplete posteriorly, leaving the discoidal cell open; this cell is sharply angulated postero-distally, and its distal side is either nearly or quite in line with its anterior side, so that it takes the form of a narrow, open slit, or V, placed obliquely to the wing-length. Discoidal field moderately broad basally, with two rows of cellules, but soon narrowing and carrying only one row for the middle portion of its length, though widening out again somewhat distally. Ms and M_3 arising close together before the level of the nodus, M_4 at or near the subnodus; M_{1A} present, also supplementary sectors below Ms and M_4 respectively; these sectors are homologous with Rspl and Mspl of recent Anisoptera. No other supplementary sectors present. Oblique vein present or absent. Cu_2 strongly arched, ending far from Cu_1, at or near the level of the nodus.

The fossil here dealt with requires a new genus for its reception.

This I propose to call *Tarsophlebiopsis* n.g. It may be distinguished from *Tarsophlebia* by the following key :—

No oblique basal piece of Cu_2 continuing the line of the distal side of the discoidal cell downwards ; no oblique vein below M_2 ; no reticulation of the median space or of the submedian, other than the supporting cross-vein at the bend of Cu_1. . . . Tarsophlebia Hagen, 1866 (Genotype, *T. eximia* (Hagen, 1862)).

An oblique basal piece of Cu_2 continues the line of the distal side of the discoidal cell downwards ; a weak oblique vein is present below M_2 a little distad from subnodus ; median and submedian spaces reticulated . . . Tarsophlebiopsis n.g. (Genotype, *T. mayi* n.sp.).

Genus Tarsophlebiopsis n.g.

(Pl. IV ; Text-figs. 1–3.)

Characters as given in the above key, to which may be added the following : Pterostigma strongly braced. Ms arising from the stem

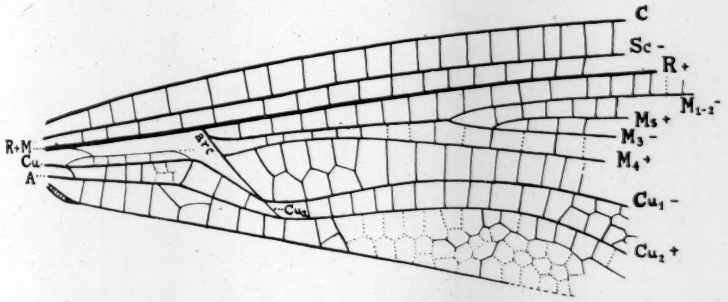

Fig. 1.—*Tarsophlebiopsis mayi* n.g. et sp. Fragment of right fore-wing, to show venation ; dotted portion restored. × 5. For lettering, see p. 152.

of M_3 at a point only a cellule or two from its origin on M_{1-3}. M_{1A} about half as long as M_2, irregularly zig-zagged for several cellules' length, then becoming a well-defined straight sector separated from M_1 by a single row of cellules, from M_2 by two or three rows. Supplementary sector below Ms (Rspl) about as long as M_{1A}, straight, separated from Ms by a single row of cellules, from M_3 by two or more rows. Supplementary sectors below M_4 (Mspl) similarly placed with respect to M_4 and Cu_1, but its basal portion zig-zagged for several cellules' length.

Genotype.—*Tarsophlebiopsis mayi* n.sp.

Horizon.—Upper Jurassic of England.

Tarsophlebiopsis mayi n.sp.

(Pl. IV ; Text-figs. 1–3.)

Fore-wing (Text-figs. 1, 2).—Total length of fragment 17 mm., indicating for the whole wing a length of about 31 mm. The fragment

shows the basal half of the wing complete up to within a cellule or so of the nodus. Number of antenodals of the first series present 20, of the second series 17. Arculus leaving R+M at an angle of about 120 degrees. M_{1-3} arising close to top of arculus, M_4 considerably further down, but the two sectors converging so as to run very close together for four or five cellules' length. Ms arising from M_3 at one cellule's length from its origin. Discoidal field with one large basal cellule, then a set of four upper and three lower cellules forming two rows, then a row of single cellules. Median space reticulated weakly, as shown in Text-fig. 2, by the development of a secondary longitudinal vein connected basally both with R+M and with Cu_1, and carrying four weak cross-veins below it. Submedian (cubito-anal) space with a short oblique vein from Cu_1 to A at extreme base, then three weak cross-veins, then two irregular,

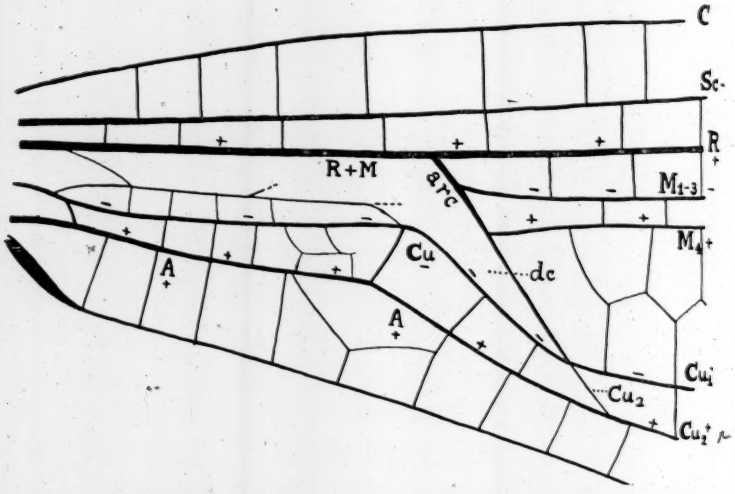

FIG. 2.—*Tarsophlebiopsis mayi* n.g. et sp. Basal part of fore-wing, further enlarged. × 17½. For lettering, see p. 152.

weakly formed cellules one above another, and finally a strongly formed brace-vein supporting the bend of Cu_1 from below. Anal or postcostal field with four single cellules followed by a large cellule divided into three by an irregular Y-shaped vein, then by four more single cellules, and finally by an increasing number of rows of smaller cellules beyond the level of the postero-distal end of the discoidal cell, where Cu_2 arches upwards; many of these latter cellules are missing in the impression, but have been restored by dotted lines in Text-fig. 1.

Hind-wing (Text-fig. 3).—Total length of fragment 21 mm.; total width of same 6 mm. This represents a wing of about 29 mm. total length by 7 mm. greatest width. The fragment comprises most

of the distal three-fifths of the wing. It can be shown to be portion of a hind-wing by taking comparative measurements of the parts preserved in common between it and the basal half of the fore-wing, but more especially by the greater angle of divergence between M_{1+2} and Ms, and the greater comparative width of the wing near its middle.

Only a very slight indication of the nodus is visible in this specimen, and the whole of the costal margin from nodus to apex is obliterated; this is restored by a dotted line in Text-fig. 3. Most of R_1 is preserved, but the part below the pterostigma is obliterated. All the veins from M_1 down to Cu_1 are complete from the basal portion of the fragment right to the apical part of the wing, and the supplementary sectors can be seen in the positions given in the generic definition. The brace-vein of the pterostigma is clearly visible, and the slight bending of M_1 beneath the position of the pterostigma away from its normal curvature indicates that the pterostigma itself must have been strongly formed, well-chitinized, and its length about the same as that of the portion of M_1 not

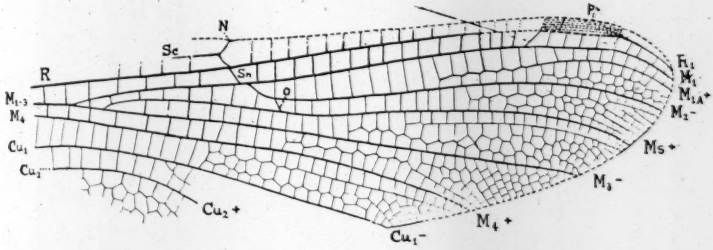

FIG. 3.—*Tarsophlebiopsis mayi* n.g. et sp. Fragment of left hind-wing, to show venation; dotted portion restored. × 4. For lettering, see p. 152.

normally curved below it; the pterostigma in Text-fig. 3 has been restored on this plan. The oblique vein (*o*) can be seen below M_2, two cellules distad from the subnodus, but not very strongly formed; M_2 itself arises very slightly distad from the subnodus. The portion of Cu_2 preserved indicates a slightly greater arching of this vein for the hind-wing than for the fore-, as was to be expected.

A small remnant of the basal posterior portion of the same hind-wing is also present, with the margin of the wing and the two rows of cellules above it very well preserved. The form of this area is in marked contrast with that of the fore-wing, and is used by Handlirsch (1908) as a subordinal character. This fragment is about 8 mm. long, and nearly 2 mm. wide at its distal end.

Both fragments of the hind-wing are deeply pigmented, while that of the fore-wing is devoid of pigment. It is well known that the colour-pattern of an insect's wing, due to pigmentation, may be preserved in the fossil impression when all traces of the original

chitin have been eliminated. This would seem to be an illustration of this fact, and would indicate that *Tarsophlebiopsis mayi* had hyaline fore-wings and deeply coloured hind-wings, as is the case with several well-known Calopteryginæ at the present day.

Type.—Portion of Ammonite with impressions of fore- and hind-wings in the matrix of the body cavity. Sedgwick Museum, Cambridge, England.

The species is dedicated to Mr. R. May, of Downing College, who discovered it.

Cawthron Institute,
Nelson, N.Z.
8th December, 1922.

REFERENCES QUOTED.

Hagen, H. A., 1862, *Palæontographica*, vol. x, p. 106 (*Heterophlebia eximia* described).

Hagen, H. A., 1866, *Palæontographica*, vol. xv, p. 65, (genus *Tarsophlebia* defined, with genotype *H. eximia* Hagen).

Handlirsch, A., 1908, Die Fossilen Insekten, etc., Leipzig, p. 467 (family Tarsophlebiidæ defined, with one genus *Tarsophlebia* Hagen).

EXPLANATION OF PLATE IV.

Fig. 1.—The fragment of the fore-wing of *Tarsophlebiopsis mayi* n.g. et sp. enlarged to show details of venation. × 6.

Fig. 2.—The fragment of the hind-wing of *Tarsophlebiopsis mayi* n.g. et sp. enlarged to show details of venation. × 6.

LETTERING OF TEXT-FIGURES.

A, anal vein. *arc.*, arculus. C, costa. Cu, cubitus; Cu_1, its upper branch, or first cubitus; Cu_2, its lower branch, or second cubitus (actually in this and many other fossil Odonata a continuation of vein A, which becomes captured by chitinization of a tracheal outgrowth from Cu_1 at the postero-distal angle of the discoidal cell, and so is secondarily attached to Cu. *dc*, discoidal cell (= quadrilateral of Zygoptera). M, media; M_{1-3} and M_4, upper and lower sectors of the arculus respectively; the former divides into M_{1+2} and M_3; M_3 gives origin to the "Zygopterid sector" Ms, while M_{1+2} gives origin further on to M_2 and continues on as M_1 to the wing-border; $M_{1\wedge}$, postnodal sector, between M_1 and M_2. N, nodus. *o*, oblique vein, formed by chitinization of a tracheal outgrowth from M_2, near its origin, and thus attaching Ms secondarily to M_2, and consequently also back to R via the subnodus. *pt*, pterostigma. R, radius. Sc, subcosta. Sn, subnodus.

The Geological Relations of the Oil Shales of Southern Burma.

By Professor J. W. Gregory, F.R.S.

THE view from the old Moulmein Pagoda, looking either westward to the sea or eastward over the plains beside the Salween, is of exceptional geological attractiveness. At the foot of the hill the Salween River passes through a breach in the Coast Range to the Gulf of Martaban. To the east picturesque monoliths, tors, and sierras rise abruptly from a vast alluvial plain which lies between the Coast Range and the distant Dawna Mountains on the Burmese side of the Siamese frontier. The interest of the view

TARSOPHLEBIOPSIS MAYI N.SP.

[To face p. 152.]

in September, 1921, was enhanced by uncertainty as to the age of the rocks. The foundation of the Coast Range consists of a blue gneiss, which is worked in large quarries to provide road metal for Rangoon. The Dawna Range, on the eastern side of the basin, is also of coarse gneiss and schist. These Eozoic rocks of both the Coast and Dawna Ranges belong to the Martaban Group of Theobald,[1] who described them as "true crystalline rocks undistinguishable in character from the ordinary gneissose rocks of Bengal". The sedimentary rocks overlying the Martaban Group belong to the Moulmein Group of T. Oldham, and have been regarded as Carboniferous on the strength of his preliminary determination in 1856 of some fossils from a limestone hill known as the "Duke of York's Nose", near Moulmein.[2] This identification has long been a matter of tradition, for the specimens were not described, and have been lost.[3] Recently, Captain Walker has collected some fossils from the same range, and, as they include *Productus*, they support Oldham's opinion.[4] On my return journey, a fortunate half-hour's delay at Martaban Station enabled me to find some specimens of *Palæanodonta*, which showed that the beds were either Permian or Carboniferous. The fossils occur in a black shale or mudstone, interbedded with a brown weathering quartzitic grit. The beds dip 30° to 10° N. of E.

Mr. John Weir, B.Sc., has identified two species, of which the more abundant is *Palæanodonta okensis* (Amalitsky)[5]; its original locality is the Middle Permian of the Oka-Volga basin, near Nizhni Novgorod; the second species, *P. subvastor* (Amalitsky),[6] was also first found in the Middle Permian of the same district. Mr. Weir notes that both the above species have been recorded by Amalitsky from the Beaufort Beds (Karroo system) of Graaf Reinet, South Africa.[7]

The Carboniferous or Permian age of some of the ridges which rise above the alluvial plain is suggested by the reported occurrence in them of coal.

From Moulmein, a steamer goes up the Gyaing River to Kyondo, whence a motor road runs inland for 15 miles to the town of Kawkareik, at the western foot of the Dawna Range. The exposures along the road are mainly of laterite, with some beds of slate, mudstone, and quartzite on some low hills, at distances from Kyondo

[1] "Geology of Pegu": *Mem. Geol. Surv. Ind.*, x, 1873, p. 140.
[2] Theobald, op. cit., p. 138.
[3] See Noetling, "Carboniferous Fossils of Tenasserim": *Rec. Geol. Surv. Ind.*, vol. xxvi, 1893, p. 96.
[4] Since my visit to the field in the autumn of 1921, it has been examined by Dr. G. de P. Cotter for the Geological Survey of India, and a preliminary statement of his conclusions is included in the General Report of the Survey, *Rec. Geol. Surv. Ind.*, vol. liv, 1922, pp. 29–30, 53–5.
[5] *Palæontographica*, xxxix, p. 193, pl. xxii, figs. 26–9.
[6] Loc. cit., p. 191, pl. xxii, figs. 30–3.
[7] *Q.J.G.S.*, vol. li, 1895, pp. 347, 348, pl. xiii, figs. 5, 6.

of 10 miles, 10 miles 6 furlongs, 11 miles, 12 miles 5 furlongs, and 13 miles. Similar slates are exposed also at mile 20 at the foot of the hills on the track northward from Kawkareik to the Third Bungalow, where, at 23 miles from Kyondo, the road begins the ascent of the mountains to reach Myawadi, on the frontier of Siam. The Dawna Range trends from north-north-west to south-south-east, but the strike of its rocks is from north-west to south-east, varying in a considerable series of observations between 310° and 330°. The predominant dip is to the south-west, but it is occasionally to the north-east, as at miles 31 and 38. The range consists of highly crystalline Eozoic rocks, of which the most abundant is bluish biotite-gneiss. This passes into white felspathic gneiss and into biotite schist. There are some intrusions of biotite-granite. A band of chloritic schist near the eastern foot of the range is probably a crushed biotite-schist, as the gneiss reappears further east. Scales of graphite are frequent, and a seam, 1 inch thick, occurs in the biotite-gneiss at 30½ miles. Pegmatite is common, and it is associated with micas 2 and 3 inches in diameter; and east of the bungalow at Sikli, which is at 34½ miles, is a dyke of pegmatite with large beryls and numerous lines of small spinels. The felspar in this pegmatite had been altered to kaolin, and within it are crystals of biotite 2 inches in diameter, which are fresh; hence, the decomposition of the felspar was clearly due to pneumatolytic action and not to weathering. At 42 miles, slate lies in a hollow at the eastern foot of the range; but the gneiss reappears on the hills to the north of the track at 45 miles, at Thingannyinnaung. Thence the main road to Myawadi continues eastward past some rugged limestone sierras. East of the Dawna Range is a series of deep basins surrounded by rugged serrated ranges, and beyond the Thaungwin River, which forms the boundary between Burma and Siam, range after range of hills reaching to the same general level indicate the former nature of the country as a dissected peneplane. Several of the basins contain deposits of oil-shale, of which the most accessible occur north of Thingannyinnaung. From that village, a forest road goes northward for 5 miles to Mepale over coarse sand derived mainly from the gneisses of the Dawna Range. The first exposure of oil shale which I saw[1] was north-east of Mepale on a path leading to the village of Tichara; we had crossed some gravels composed of coarse white quartzite, and reached an exposure of oil shale dipping

[1] During my visit to the Tichara field I had the benefit of the company and guidance of Mr. R. H. Crozier, the consulting mining engineer and metallurgist to Messrs. Moolla Sons, Ltd., who hold a lease of the property. In my inspection of the field I also received courteous help from Mr. Krull, who was specially helpful in collecting fossils, and from Messrs. Wood, who are conducting the boring; I am also much obliged for subsequent information as to the boring results from Mr. H. F. Lang, the Manager of this department of Messrs. Moolla's enterprises.

eastward. As the beds beside it looked favourable for the preservation of fossils, we examined them, and after a short search the first fossil from the basin was discovered by my guide and companion, Mr. R. H. Crozier. It was a Dicotyledonous leaf, which has been determined by Mr. Edwards as Phyllites; it was sufficient at once to disprove the belief that the oil shales are Carboniferous in age, for this fossil showed that the beds are relatively modern.

The Tichara oil shales lie in a basin, most of which appears to be underlain by the Dawna gneiss, for large cobbles of that rock and of schistose quartzite are frequent in the basin, and outcrops of gneiss from beneath the oil shales are seen near the eastern and northern margins.

The best exposures of the beds associated with the oil shales are in the banks of the Mepale Chaung. By the kindness of Mr. R. H. Crozier, I was able to descend this river on a bamboo raft and thus examine the sections; as the river was high, many of the exposures were covered, and some beds of oil shale which Mr. Crozier had seen on a previous raft journey were not accessible. We began the descent of the river from a point $2\frac{1}{4}$ miles in a direct line north-west from Mepale Bridge. The first exposures were of a green shale, there bent into a broken anticline, of which the axis trends to 70°; on the northern side, the dip was 25°, and on the southern 5°. These green shales were in places nodular, and contained leaves similar to those near Mepale. Further down stream, well jointed green shales are succeeded by dark blue and buff sandstones, some of which were in beds about a foot in thickness; in turn, above these beds are limestone and a layer with masses of white fossil wood, of which a specimen collected by Mr. Krull came from a trunk at least 1 foot in diameter; the wood, however, Mr. Edwards finds to be indeterminable except as a Dicotyledon. The cliff on the south side of Mepale Bridge exposes a series of sandy shales, dipping 18° to 60°, with two beds of limestone each 4 inches thick, and between them a three-quarter inch layer of fibrous calcite. Below Mepale, after passing the junction of the Bawtalu Creek, we saw a seam of oil shale dipping to north-east. At the end of the next southward bend of the river, the oil shales dip 6° to south-south-east. A little further down the river occur beds of limestone overlying black shales. These limestones are different in appearance from those on Mepale bridge, and are probably on a higher horizon. Some banded limestones with a seam of fibrous calcite, which outcrop at the end of the succeeding bend of the river after a course to south-south-east, are similar to those at Mepale bridge; they dip to west-north-west, and probably represent an outcrop of the beds seen at the bridge. To the east of these exposures, black shales, opposite the entrance of Tichara Creek, dip $2\frac{1}{2}$° to the north-west and strike to 35° E. of N. A little further downstream on the northern bank are the shales which yielded the fossil pods referred by Mr. Edwards to *Leguminosites*.

After this point the beds, as far as the great hairpin bend of the river, consist of soft sandstones dipping 32° to 10° E. of N.

North-west of Tichara the country is covered with dense forest, with only occasional exposures in the stream beds; three-quarters of a mile north of Tichara village, a leaf bed, containing the plants determined by Mr. Edwards as new species of Dipterocarpophyllum and Ficophyllum, is exposed on the bank of a small stream and immediately overlies a seam of oil shale. Further to the north-west the gravels contain large pebbles of quartzite and biotite-gneiss, indicating outcrops of the Eozoic rocks either on the floor of the basin or a short distance to the north. Still further on, stream sections show greenish and blue sandstones, and a band of oil shales rises above the soil with strikes of approximately west-north-west to east-north-east (110° and 125°), with dips of 35° and 50° southward.

The basin to the north of Tichara ends at the foot of a rough limestone range near a bungalow of the Forest Department. These limestones appear to be of excellent quality, but I obtained no evidence as to their age; for a short search yielded only indeterminable fossils. Dr. Cotter has found along the Thaungwin River, to the east of the oil shale field, some fossils which have been determined by Mr. Tipper as Lower Mesozoic.[1] They are clearly much older than the oil shale series.

East of Tichara village, the basement rocks are exposed in some hills of schistose quartzite and gneiss about 2½ or 3 miles from the village. Fragments of silicified fossil wood occur on the slopes of these hills, and a stream bed is strewn for a length of 60 yards with blocks of a shelly, freshwater limestone. Part of it has been silicified into chert. The blocks are often 2 feet thick. Above this rock lies a white limestone, and further above it to the west are some shales containing white fossil wood like that seen in the section west-north-west of Mepale bridge, and a compact limestone and fibrous calcite also like those of Mepale.

The evidence, therefore, indicates that the oil shales occur in the upper part of a series of freshwater deposits, of which the lower part, well seen near and west of Mepale, may be classified as the lower or Mepale beds; they include green jointed shales, sandstones, and limestones, which yielded no fossils in the south-western part of the field, but which in the eastern part contain shelly limestone. The upper or Tichara beds include the seams of oil shale, which have been proved on a line passing north and south to the east of Tichara; along this line they dip westward, while other occurrences which have not yet been prospected are seen west of the village, where they dip eastward. To the north of Tichara the oil shale dips southward, and judging from the observed dip of the sandstones and shales in the Mepale Chaung, the lower beds rise to the surface near the river and the shales should there dip to the north.

[1] Cotter, op. cit., p. 54.

The oil shales themselves are clearly lake deposits. They include coarse, micaceous sandstone with abundant flakes of white mica, false-bedded finer-grained sandstones, thin, sharply-defined alternations of black and grey clay, each of which was probably deposited by a separate flood, false-bedded and corrugated shales, cream-coloured marl, and marly limestone, some of which has markings like an imperfect landscape marl. Carbonaceous material is widely distributed, occasional layers contain small cubes of pyrites, but its amount is so limited that the quantity of sulphur present is apparently small.

The beds are often well jointed, and they have been broken by many small faults. Some of the bore cores show small parallel faults with a throw of an eighth of an inch. The faults are often in parallel series, and some form trough faults, in which the faults are either normal or overthrust on both sides; the reverse faults were probably caused by the subsidence of the beds down the sloping sides of the lake. In some cases the beds have been buckled into small wavy folds, doubtless by the same cause. The throw of some of the faults has been sufficient to produce large slickensided surfaces marked by vertical or horizontal striae; and in one case seen the fault was inclined at an angle of 40° from the horizontal.

The oil shales themselves have been shown by the prospecting operations, conducted under the supervision of Mr. H. F. Lang, to occur in seams which have been followed along a belt running southward to the east of Tichara village. Eight distinct seams have been found. These beds dip to the west along the outcrop series near Tichara, and the boring operations have shown that the shales are unusually persistent in their lateral extension.

The microscopic structure of the oil shales shows that the rich material consists of a base of clay containing small quartz grains and an organic material which is yellowish to brown by transmitted light and which serves as the kerogen. The shales differ from those of Scotland and Australia by the absence of the well-defined spheroidal yellow bodies which may be regarded not as algæ, as suggested by Bertrand and Renault, but as spherocrystals of an organic product similar to those of inulin. Spore cases often occur in Carboniferous oil shales, but the characteristic yellow bodies are different in origin from them. In the sections so far cut from the Tichara oil shales, there are no yellow bodies, but abundance of material from which yellow bodies could have been formed as sphero-crystalline segregations. The absence of these bodies in the Mepale oil shales may be explained by their geologically recent age, which is probably Pliocene.

The fossils collected include freshwater mollusca, from a limestone of which part has been silicified into chert. This rock was examined in situ in a stream bed about 2½ miles east of Tichara village, on the eastern edge of the shale basin. Fragments of the same rock were found near pit No. 3 and in the Mepale River near the junction

with the Tichara Creek; in these two cases only loose boulders were found, which may have been carried by the natives; otherwise they would indicate adjacent outcrops of the limestone. A native told me that the rock occurred in the stream near pit No. 3, but failed to guide me to the place. The shells from this limestone have been kindly identified by Dr. Annandale, who is describing my collection and that subsequently made by Mr. G. de P. Cotter, in a paper to be published by the Geological Survey of India. Dr. Annandale's list of species is as follows:—

Fam. MELANIDÆ.	*Acrostoma intermedium* Annandale (sp. nov.).
	Acrostoma cotteri Annandale (sp. nov.).
Fam. VIVIPARIDÆ.	*Vivipara dubiosa* Annandale (sp. nov.).
	Vivipara gregoriana Annandale (sp. nov.).
Fam. UNIONIDÆ.	*Indonaia bonneaudi* (Eyd.).
	Indopseudodon (?) *rostratus* Annandale (sp. nov.).
	Lamellidens (?) *quadratus* Annandale (sp. nov.).

As six of the species are extinct, the fauna is not likely to be later than the Pliocene. As all belong to genera still living in this part of Asia, as and Dr. Annandale remarks that of the four gastropods two are related to living Burmese species, as one of the Unionids is a living species, and as of the other two Dr. Annandale notes their resemblance to living species, the age need not be much if any pre-Pliocene. The Pliocene age is also rendered probable by the stratigraphical evidence; for the beds have not been distributed by the earth movements which affected this part of Asia in the Lower and Middle Kainozoic.

A small but complete specimen of a fossil fish from a limestone at pit No. 3, Dr. Smith Woodward tells me, may also be of Pliocene age.

Fragments of fossil plants are numerous, and my collection has been kindly examined by Mr. W. N. Edwards. The determinable plants came from the oil shale series; indeterminable fragments of fossil wood occur associated with the shell-bed, and similar wood was found in the north-western part of the field, and fossil wood was also abundant in the lower series in the western area. The pods described by Mr. Edwards as *Leguminosites albizziformis* and *L.* sp. were collected from the banks of the Mepale River, near the confluence with the Tichara River, at an horizon close to an oil shale, which is probably one of the lowest of the Tichara seams. The *Phyllites* sp. obtained on the western margin of the Tichara shale area is also from the lower part of the shales as the fossiliferous bed there is near an occurrence of gneiss. The *Ficophyllum burmense* and *Dipterocarpophyllum gregoryi* come from a higher horizon; they were found beside a bore (No. 3), three-quarters of a mile north of Tichara village, from a bed just below the fourth of the seven proved seams of oil shale counting upward from the main outcrop seam east of Tichara.

Mr. Edwards concludes that there is nothing in this flora inconsistent with the Pliocene age of the deposits.

Summary of Conclusions.—The oil shales of the Mepale basin are of interest owing to their relatively recent geological age. They were formed as lake deposits, of which a Pliocene age is rendered probable by the combined palæontological and stratigraphical evidence. The oil shales occur in the upper part of the series of lake deposits. The evidence of the bores shows that the oil shales are remarkably persistent along the belt hitherto prospected. They lie in a basin surrounded on most sides by Eozoic gneiss and schistose quartzites. The northern rim includes some limestone: fossils collected by Dr. P. de G. Cotter indicate that part of the local limestone is Lower Mesozoic (probably Triassic), but some of it may represent the Carboniferous limestones of near Moulmein. The Martaban grits are Permian.

On some Tertiary Plants from South-East Burma.

By W. N. Edwards.

(PLATE V.)

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THE small collection of fossil plants from Burma here described was made in 1921 by Professor J. W. Gregory, in the neighbourhood of Tichara and the Mepale River, near the Siamese frontier, east of Moulmein. Tichara is a few miles north-west of Myawadi, on the frontier of Siam, and 14 miles to the north-east of Kawkareik. It is a little north of the Mepale River, which flows south-eastward into the Thaungyin, on which Myawadi stands.

The plants are preserved in a light-coloured and rather soft fissile shale, and some of the impressions are extremely good, though none of the original cuticle remains. Associated with the plants are some fragmentary fish and Arthropods.

Professor Gregory kindly handed the plants to me for examination, and I am also indebted to Dr. A. B. Rendle and Mr. E. G. Baker, of the Botany Department, British Museum of Natural History, for valuable help and suggestions. The figured specimens are preserved in the Geology Department of Glasgow University; the counterparts of some of them are in the British Museum (Natural History).

Description of Specimens.

Family Moraceæ (?).

Ficophyllum Font. em.

This genus was instituted by Fontaine (1889, p. 290) for leaf-impressions of Lower Cretaceous age, which he considered to have an "archaic type" of venation, although he states that "there is a general and strong resemblance between these plants and some species of *Ficus*". Following the suggestions of Nathorst (1886,

p. 91), I propose to use the name *Ficophyllum* in a wider sense to include fossil leaves which resemble those of the living genus *Ficus*, but which cannot be referred to it with absolute certainty. In the absence of evidence from cuticular structure, association with fruits, and so on, it does not seem to me desirable as a general rule to refer fossil leaf impressions to recent genera, especially when the form and venation are of a common and widespread type.

Ficophyllum burmense sp.n. (Pl. V, Fig. 1.)

Leaf ovate-lanceolate, entire, petiolate, slightly asymmetrical, subacuminate, base subcuneate; venation camptodrome, brochidodrome, midrib strong, secondary veins relatively fine, about 12 on each side, unequally spaced, making angles of 55 degrees to 85 degrees with the midrib, connecting loops running about 1 mm. from the margin and curving inwards above, tertiary and quaternary veins enclosing a fine ultimate network. Length 4·5 cms., greatest width 1·7 cms.

Locality.—Beside a stream, three-quarters of a mile north of Tichara village.

The venation of this leaf recalls that of several diverse genera figured by Ettingshausen in his work on dicotyledonous leaves, such as *Pachira* (Ettingshausen, 1861, p. 123), *Ticorea* (ibid., p. 183), *Sapindus* (ibid., pl. lxi, fig. 11), and *Swartzia* (ibid., pl. xciii, fig. 9), but the resemblance is perhaps greatest to some species of *Ficus* (cf. *Ficus americana*, pl. vii, figs. 4 and 6, and *F. venosa*, pl. viii, fig. 4, 5). Among other recent species of a similar type may be mentioned *Ficus infectoria*, Roxb. (see figures by King, 1887–9, pl. lxxv), *F. scandens*, Roxb., and *F. parasitica* Koen., all of which occur in the Indo-Malay region. I have not, however, met with any species which agrees in venation absolutely with the fossil, but there is often some variation even within a single living species. Form and venation alone are not sufficient for the exact generic reference of the fossil leaf, and certainly not for a specific identification; but as there is a very considerable resemblance to one of the several types of *Ficus* leaf, I propose to name the present specimen *Ficophyllum burmense*, n.sp.

Family Dipterocarpaceæ.

Dipterocarpophyllum, nom. nov. Fossil leaf impressions resembling those of the *Dipterocarpaceæ*, but not certainly referable to any one of the living genera.

Dipterocarpophyllum gregoryi, sp.n. (Pl. V, Fig. 2.)

Leaf oblong, entire, slightly asymmetrical, petiolate, with a wing or swelling on the petiole just below the base of the lamina, which is slightly oblique; venation camptodrome, midrib strong, secondary veins strong, at least sixteen on each side (the apex is incomplete), arising at angles of 50–80 degrees (average 55 degrees) and pursuing

a more or less parallel and nearly straight course at only slightly varying intervals, curving upwards about 2 mm. from the margin, into which they gradually pass ; tertiary veins fine, distinct, running sinuously parallel to each other and nearly at right angles to the secondaries, occasionally branched ; quaternaries mainly connecting the tertiaries more or less at right angles.

Length of specimen, including petiole, 9·5 cms. (incomplete). Breadth 3·4 cms.

Locality.—Beside a stream, three-quarters of a mile north of Tichara village.

Although the type of venation seen in this fossil occurs in various living genera, such as *Artocarpus*, *Briedelia*, *Rhamnus*, and *Pouroma*, there can, I think, be little doubt that the specimen is referable to the *Dipterocarpaceæ*. The venation is closely similar throughout the family, and the swelling on the petiole just below the lamina is characteristic. The generic attribution is, however, uncertain, and I have therefore made use of the term *Dipterocarpophyllum*, naming the species *D. gregoryi* after Professor J. W. Gregory. The fossil recalls certain species of *Dipterocarpus* and *Hopea* (e.g. *H. philippinensis*), but the resemblance to some leaves of *Anisoptera*, *Vateria*, *Stemonoporus*, *Shorea*, and *Parashorea* makes it difficult to hope for an exact determination in the absence of fruits. In the genus *Dipterocarpus*, *D. oblongifolius* Blume may be taken as an example of a species with leaves of a similar shape as well as venation, while in *D. hasseltii* Blume the petiolar swelling is particularly well-marked, and appears in herbarium specimens almost like a wing, as in the fossil. In size and shape (as well as venation) there is a close resemblance to some species of *Shorea* and *Parashorea*, particularly *Parashorea stellata* Kurz. The asymmetry and slight inequality at the base of the lamina is unlike the normal Dipterocarpaceous leaf, but I have seen specimens of *Dipterocarpus* in which symmetrical and slightly oblique leaves occur on the same twig. In *D. basilanica* F. W. F. the leaf is sometimes slightly asymmetrical.

The family extends at the present day from the Seychelles to New Guinea, with its main centre in India, and species of *Dipterocarpus* and other genera are common in Burma. Several fossil members have been described from leaves, fruits, and wood, and they may be briefly considered here. The fruits are unmistakable, and Heer (1874, p. 15) recorded a well-preserved specimen from the Tertiary of Sumatra as *D. verbeekianus*. In a further contribution Heer figured (1883, p. 19) two leaves, *D. antiquus* and *D. atavinus*, from the same formation. These may well be considered as belonging to the family, particularly the latter, which shows the petiolar thickening (pl. vi, fig. 4).

The specimens from Borneo, on the other hand, described by Geyler (1877) as *Phyllites* (*Hopea*) *præcursor* (pl. ii, fig. 2) and *Carpites* (*Dipterocarpus*) *pengaronensis* (pl. ii, fig. 4), are not, in my opinion, determinable and are worthless as records of the family.

Some leaves from Labuan were named by Geyler (1887, p. 499) *Dipterocarpus labuanus*, *D. nordenskioldi*, and *D.* sp. An examination of the originals in the Stockholm Museum recently did not convince me as to the certainty of the attribution. The specimen figured as *Dipterocarpus* sp. (pl. xxxvi, fig. 6) is an indeterminable fragment, and the other two, which are also very fragmentary, may conceivably be Dipterocarpaceous, but are not definitely identifiable.

The Pliocene of Java has yielded a leaf very similar in venation to members of this family, which has been cautiously described by Crié (1888, p. 14, pl. v, fig. 1) as *Phyllites dipterocarpoides*, and is compared with the living *Dipterocarpus baudii* Korth.

More recently fossil wood belonging to the *Dipterocarpaceæ* has been found in various Tertiary localities in the East. Miss Holden (1916) describes *Dipterocarpoxylon burmense* from Gwedindon in the Sagaing district, Burma, but she gives no indication of the age of the beds in which it was found, except that it is Tertiary (p. 270). Mlle. Colani (1919) records *Dipterocarpoxylon annamense* from presumed Tertiary beds of Annam, and Kräusel (1922 *a*) has found that wood of this family (*D. tobleri* and *D.* sp.) is common in the Miocene of South Sumatra. He also refers *Grewioxylon swedenborgii* Schuster, from the East Indies, to the genus *Dipterocarpoxylon* (1922 *a*, p. 267). Finally Kräusel (1922 *b*) describes *D. javanense* from the Tertiary of Java, but I have not yet seen this paper.

Thus, though there are several records of fossil members of this family in the East, information as to their horizon in the Tertiary is usually lacking, except in the case of Crié's Pliocene leaf and Kräusel's Miocene wood.

It is of interest to recall that the English Lower Greensand wood, *Woburnia porosa* Stopes, has been compared with the Dipterocarpaceæ, so that the family may have had a long geological history and a more extended distribution in the past.

Phyllites sp.

A further fragment of a dicotyledonous leaf, not belonging to either of the above species, was found south-west of Tichara village, but is quite indeterminable.

Family Leguminoseæ.

Leguminosites albizziformis, sp.n. (Pl. V, Fig. 3). Pod broad, contracted slightly between the seeds, resembling that of the recent genus *Albizzia*.

Locality.—South bank of the Mepale River, opposite confluence with Tichara Creek.

The single, incomplete specimen is 2·5–3 cms. broad, and consists of about 9 cms. of the distal portion of a pod, with three seeds. This fruit recalls those of the genera *Inga* and *Albizzia*, and particularly the species *Albizzia lebbek* (L.), which is common in the East, including Burma, and to which the fossil may quite possibly belong. The provisional name *Leguminosites albizziformis* is proposed for *Albizzia*-like fruits, which cannot be identified with certainty.

Leguminosites sp. (Pl. V, Fig. 4.)

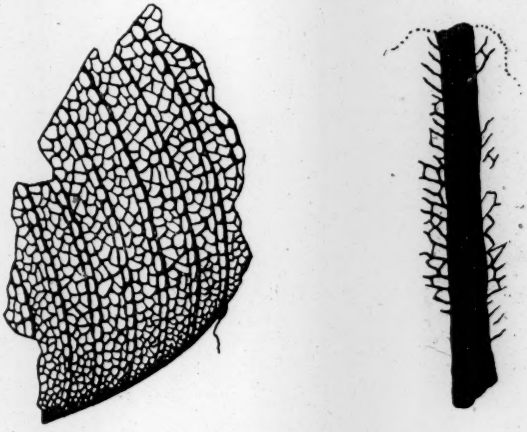
A second specimen of a leguminous pod from the bank of the Mepale River, east of the junction of Tichara Creek, evidently belongs to a different species, but is of a commoner type than the foregoing. It is 1·8 cms. broad and 11 cms. long, but is incomplete, and shows the presence of seven seeds. The margins are practically parallel, and the apex tapering and somewhat rounded. It is probably one of the Mimoseæ, though some of the Cæsalpineæ have a similar pod, but even with further and better material it would be difficult to assign it to a living genus.

Dicotyledonous Wood.

There is one specimen (No. 102) of dicotyledonous wood from the Mepale River, above and west of Mepale, which is too poorly preserved for identification. There are also some water-worn pieces of what might be fossil wood, but which show no structure; they may have been derived from some earlier formation.

Plantæ Incertæ Sedis. (Fig. 1*a* and *b*.)

The two fragments shown in Text-fig. 1 may perhaps belong to the same species. At first sight it seemed that they might be some



a *b*

Fig. 1.—Plantæ Incertæ Sedis. Mepale River. About twice natural size.

monocotyledonous water plant, such as one of the Potamogetonaceæ or Aponogetonaceæ, but this seems very doubtful. The regular arrangement of the network in Fig. 1*a* is noticeable, with rows of rectangular areas separating bands of four or five rows, where the areas are more polygonal. Such a definite structure should prove useful in identification, but I have not met with anything exactly like it. There is an approach to it in *Acrostichum excelsum*, and a somewhat similar arrangement on a small scale occurs in some

species of *Salvinia*. Further search might reveal better specimens, showing the outline of the leaf or frond, which must at present remain undetermined.

Associated with these fragments are several pieces of stem or rachis, some with longitudinal striations.

Locality.—Bank of the Mepale River, east of junction with Tichara Creek.

Insect Remains.

These were kindly examined for me by Messrs. F. Laing and F. W. Edwards, but pronounced indeterminable. One specimen, from a pit (A/6) about a third of a mile east-north-east of Tichara, shows numerous small bodies, about 1–1·5 mm. long, which are quite possibly collembolids, together with a doubtful beetle. Another specimen, from a pit (No. 3) about 7 furlongs south-south-east of Tichara, shows the impression of an insect-wing. There are no other recognizable Arthropod remains.

General Conclusions.

It will be seen that the recognizable vegetable remains in this collection are rather meagre; one leaf belonging to the *Dipterocarpaceæ*, a possible *Ficus*, and two leguminous fruits, in addition to some dicotyledonous wood and a few fragmentary and inconclusive impressions. It is therefore difficult to obtain any satisfactory idea of the age of the beds in which they were found, especially in view of the comparative poverty of our knowledge of fossil floras of the eastern tropics in general. The plant assemblage certainly indicates a Tertiary age, and from the resemblance of some of the forms to species now living in Burma, the later rather than the earlier part of the period is indicated. I understand that the animal remains found in association with the plants suggest a Pliocene age, and there is nothing in the plant evidence which would contradict this view.

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TERTIARY PLANTS FROM BURMA.

To face p. 165.]

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EXPLANATION OF PLATE V.

Fig. 1.—*Ficophyllum burmense*, n.sp. $\times\frac{4}{3}$.
Fig. 2.—*Dipterocarpophyllum gregoryi*, n.sp. $\times\frac{1}{1}$.
Fig. 3.—*Leguminosites albizziformis*, n.sp. $\times\frac{5}{3}$.
Fig. 4.—*Leguminosites*, sp. $\times\frac{1}{1}$.

Notes on Petrographic Methods.

By P. G. H. Boswell.

MANY workers in the domain of the petrology of sedimentary rocks will welcome the article by Dr. Rastall in the Geological Magazine for January, 1923, and will appreciate the fact that certain notes therein help to make clear what may or may not reasonably be expected from this branch of geology. Judging from what has been said and written from time to time, I fear there is some amount of misconception as to what is being and has been achieved by the study of the rarer minerals and grain-size of sediments. As Dr. Rastall has paid me the compliment of referring to certain work with which I was concerned, in part during the war, it may be of interest and service if I indicate briefly the character of some of the work done and the utility of the petrographic methods adopted.

First, it should be emphasized that much of the advisory work done during the war depended on collections made and investigations prosecuted in pure scientific research before 1914. The war had hardly begun when there arrived inquiries which could only be answered by reference to existing collections and data. The work subsequently carried out may be indicated under four main heads :—

(1) The substitution of British sands, sandstones, and other sediments for foreign supplies having a very similar petrographic character.

(2) The investigation of other possible British resources, not necessarily identical with foreign materials, and the improvement and modification of works' methods and treatment to permit their use.

(3) The reduction of internal transport by the discovery and exploitation of home supplies of geological materials close to the area of consumption.

(4) The establishment of a check on all supplies entering works in order to ensure no unauthorized substitution or contamination of raw materials.

In addition, investigations were carried out in connexion with treatment and preparation of supplies in quarries and works, but it is not necessary to add details of these.

Of the various branches of petrographic technique involved, most confusion of mind seems to exist in the matter of the determination of (*a*) grade sizes and proportions by elutriation, (*b*) mineral composition, especially as regards the "heavy residues". The citation of a few examples may remove misapprehension.

Sands for high-class glass manufacture.—The grading as determined by elutriation or sieving was of great importance. Heavy residues were of importance only, except as indicated under (4) above, if amounting to more than 0·05 per cent, and containing iron-compounds and minerals such as ilmenite and rutile, difficult of solution in the melt. The limit of iron oxide (estimated as Fe_2O_3) for good optical glass being 0·02 per cent, it is easily understood that even a "pure white" quartz sand might be unsuitable on account of its "heavy crop". Such sands were, however, utilized in some works by screening or washing out the fine grades containing the grains of heavy minerals of small diameter, when high-class sands resulted.

Sands, etc., for foundry purposes (*moulding, etc.*).—Elutriation was the only method by which accurate determination of the mechanical composition could be made. Sieving was of no value, since the essential characters in many cases were a low silt-content and fairly high clay-content. The presence or absence of "heavy minerals" was apparently immaterial. The mineral composition of the bulk of the material was of importance so far as the question of refractoriness to heat was concerned.

The investigation of the heavy mineral assemblage was, however, undertaken in the case of every deposit exploited for the reason mentioned under (4) above. Once a works had embarked on a successful course of manufacture, it was essential that the raw materials should not be changed. This was particularly the case where mixtures from several sources were utilized, as in steel-foundry practice. Difficulties of transport, abnormal climatic conditions, and other causes led to attempts being made to supply substitutes. Such attempts often led to disaster. A knowledge of the general characters (including mechanical composition) and heavy mineral assemblage enabled the investigator to identify any British sediment and even to detect contamination or substitution in mixtures. For obvious reasons actual examples cannot be cited.

Amongst other questions of technique, Dr. Rastall raises that of the value of elutriation of sediments of mixed mineral composition. Obviously, if a considerable proportion of minerals of different densities are present, as in many shore-concentrates, elutriation yields results of no value. The great majority of sediments, however, consist in their coarser grades of quartz and felspar,

on the so-called " hydraulic values " of which the usual elutriation calculations are based. The proportion of heavy minerals rarely exceeds one per cent. The experimental and other errors in elutriation, due to various causes—small temperature changes, non-spherical shape of grains, friction on the sides of the vessels, etc. —exceed this amount in my experience. In such sediments, therefore, the error due to presence of heavy minerals, divided as it is amongst several grades, is less than the experimental errors. As the grade of the sediment becomes fine, the density of the minerals present, according to Stokes's Law and its modifications, becomes of decreasing importance when compared with their surface area, and only a very small error is introduced by assuming the density to be that of quartz.

All the figures upon which the technique of elutriation and the older subsidence methods are based require revision. In a short paper published recently in the *Transactions of the Faraday Society* (vol. 18, 1922, part i), I attempted to clear some of the ground, but lack of time has prevented the continuation of the work. Serious discrepancies are observed between the calculated values of the final velocities of small grains subsiding in fluids, whether obtained from Stokes's formula or Ladenberg's modification of that formula.

Just as the old subsidence methods have given place, in the necessity for greater accuracy, to those of elutriation, so in turn it seems probable that elutriation may be superseded for purely scientific work by automatic subsidence methods of the type devised by Dr. Sven Odén.[1] For detailed work on the mechanical constitution of sediments, elutriation is at the best but a crude method which will doubtless be improved upon in due course, although the separations when examined microscopically appear highly satisfactory. Commercially, the procedure will probably persist, for it is effective in separation and yields results easy of comparison. The data obtained by elutriation are at present not susceptible to simple mathematical treatment, but they can be expressed empirically in the form of curves which are of considerable use for comparing sediments with one another and indicating the degree of perfection of the sorting of their constituents according to size. It is for this reason that, although I possess the results of many hundreds of analyses, I have refrained from publishing long lists of figures, except for economic purposes where delay was inadvisable. For the present the best course seems to lie in representing only typical or extreme analyses in curve form.

In the matter of size-limits and nomenclature of grades, I agree with Dr. Rastall that it is unfortunate that more uniformity has

[1] " Allgemeine Einleitung zur Chemie und physikalischen Chemie der Tone " : *Bull. Geol. Inst. Upsala*, vol. xv, 1916, p. 175 ; and " On the Size of the Particles in Deep-Sea Deposits " : *Proc. Roy. Soc. Edin.*, vol. xxxvi, pt. iii, No. 13, 1916.

not been adopted. Nevertheless, amongst petrologists, as distinct from agriculturists and others, there is a certain uniformity in the grade-sizes adopted in this country, the United States, Denmark, and Germany. One of the few points of difference is the limit 0·25 mm., for which 0·2 mm. is sometimes substituted.[1]

If, however, the mechanical composition of a sediment is expressed by means of a curve, or calculated from such a curve, the exact size-limits adopted are immaterial, for the same sediment should yield the same curve whatever arbitrary points of measurement are taken. Moreover, in the case of each of the somewhat different methods of plotting curves adopted by the Danish Geological Survey, Dr. Baker and myself, it is possible to determine, within a certain limit of error, the mechanical composition of the sediment expressed in any size-limits desired. Thus we may plot the curve from data involving the size-limits 2·0, 1·0, 0·5, 0·25, 0·1, 0·05, 0·01 mm., and from it determine the percentages for such arbitrary size-limits as, say, 1·5, 0·75, 0·4, 0·04 mm., and so on.

The most serious objection to Dr. Odén's procedure lies in the lengthy and difficult mathematical transformations involved in constructing the "Distribution Curves" from the "Accumulation Curves". I understand, however, that mechanical methods of effecting these transformations are being devised.

Dr. Rastall's remarks on sieves and wire-woven screens leave me impenitent. There is a lower limit of $\frac{1}{2}$ mm. to the size of aperture in the construction of round-holed sieves, which yield, of course, less inaccurate results than those of square mesh. Wire-woven screens when measured under the microscope show extraordinary variation, and cases where the diameter of aperture has varied with the market-price of metal have been noted. The I.M.M. screens are, of course, standardized, but their lower limit is reached at 200 meshes to the linear inch.

The Massive Chert Formation of North Flintshire.[2]

By H. C. Sargent, F.G.S.

(PLATE VI.)

Introduction.

In the Geological Survey Memoir, "The Geology of the Coasts adjoining Rhyl, Abergele, and Colwyn," Mr. (now Sir Aubrey) Strahan most truly observes (p. 18): "There is in scarcely any part of this country a more remarkable development of chert than that which overlies the Carboniferous Limestone of North Flintshire."

[1] See for example: K. Keilhack, *Lehrbuch der praktischen Geologie*, 3rd ed., vol. ii, 1917; H. Ries, *Clays, their Occurrence, Properties, and Uses*, 2nd ed., p. 141, 1914; T. Crook, Appendix to Hatch and Rastall, *The Sedimentary Rocks*, p. 343, 1913; H. A. Baker, "Mechanical Constitution of Loose Arenaceous Sediments": Geol. Mag., Vol. LVII, 1920, p. 323; P. Harder, "Undersögelser over nogle danske Sandsorters Avendelighed til Formsand i Jernstöberier": *Dan. Geol. Undersög.*, ser. ii, No. 16, 1905.

[2] Paper read before the Liverpool Geological Society, 14th November, 1922.

The purpose of this paper is to describe the field-relations and petrography of this formation, and to consider the conclusions that may be drawn therefrom.

The term "chert" is used to signify a non-clastic sediment consisting essentially of crypto- or microcrystalline silica, and having typically a vitreous lustre and conchoidal fracture. Both lustre and fracture are frequently lost, in this formation, by admixture of calcium carbonate or detrital material. The rock then often assumes a finely granular aspect, and may pass into a siliceous limestone or bastard chert, or a gritty chert. When iron impurity beyond a limited amount is present, loss of vitreous lustre appears also to result from the oxidation of ferrous to ferric oxide.

A cherty sandstone, as the name implies, is a clastic sediment consisting mainly of detrital grains of chert and quartz. Both gritty chert and cherty sandstone occur in North Flintshire, and since they are often difficult to distinguish in hand specimens, not only from each other, but also from a true quartz sandstone, their real character can only be determined by microscopic examination.

Field Relations.

These cherts and the sandstone into which they are said to pass horizontally southwards [1] were formerly referred to the Millstone Grit Series. That view is now abandoned, and the chert and sandstone together, under the rather inappropriate name of the Cefn-y-fedw Sandstone Group, are considered to form the topmost member of the Carboniferous Limestone Series.[2]

Hind and Stobbs[3] state that, though the fauna is extremely scanty, it has a Carboniferous Limestone facies. Wherever the junction is seen the cherts rest on beds with a *Cyathaxonia* fauna, the range of which embraces the highest beds of the limestone and the overlying passage-beds. The latter, usually thin limestones with shale-partings, may be seen underlying the chert in Trelogan Quarry; in Grange Quarry, near Holywell; and at Waenbrodlas, on Halkyn Mountain. It may be noted, in passing, that the passage-beds are not persistent, but thin out rapidly going south. At Trelogan, some of the shale-partings are up to 3 feet in thickness; at Waenbrodlas, they have much diminished, and further south they disappear altogether. In an old quarry on the south-east side of Moel-y-Gaer chert is seen resting directly on grey limestone.

[1] Cf. Strahan, "The Geology of the Neighbourhoods of Flint, Mold, and Ruthin": *Mem. Geol. Surv.*, 1890, p. 47 et seq.

[2] Cf. B. Smith, "Special Reports on the Mineral Resources of Great Britain"; vol. xix, "Lead and Zinc Ores in the Carb. Rocks of N. Wales": *Mem. Geol. Surv.*, 1921, pp. 36 and 38.

[3] Wheelton Hind and J. T. Stobbs, "The Carboniferous Succession below the Coal-Measures in North Shropshire, Denbighshire, and Flintshire": Geol. Mag., 1906, p. 502.

Overlying the cherts on the east, and overlapping them, as will be shown below, at other points of the outcrop, there is a series of thin black limestones and shales (Holywell Shales), which Hind and Stobbs [1] have shown to possess a *Posidonomya* fauna, and there seems no doubt that they form the south-western extension of the Pendleside beds, which attain their maximum thickness on Pendle Hill, whence they thin out north, west, and south.[2] These authors call attention to the intimate relation of the North Wales development of these beds with the larger Pennine area.[3] They may be seen overlying the chert near Gronant; on the hillside south of Prestatyn; and at Grange Quarry, near Holywell.

The outcrop of the chert has a general south-east strike from Gronant (near the north coast of Flintshire), through Llanassa, Trelogan, Grange near Holywell, and Halkyn Mountain as far as Moel-y-Gaer, beyond which I have been unable to trace it. (See map, Fig. 1.)

It has been stated, as noted above, that when traced southward, the chert passes horizontally into sandstone and becomes progressively coarser.[4] There appears, however, to be good evidence to show that the chert and the sandstone are two distinct formations, probably derived from different sources, the sandstone overlying the chert. The sandstone may be seen in Pen-yr-hwylfa Quarry, on the north of Halkyn Mountain, resting on the chert as a distinct bed. It is here about 9 feet thick, and contains at the base abundant detrital fragments of chert, although there is no visible unconformity (Pl. VI, Fig. 5). In the underground levels of the Halkyn Mines, on the east of Halkyn Mountain, the chert is seen dipping below the sandstone with a bed of shale between.[5] The shale is mapped at the outcrop (Sheet 79 S.E.).

The relations of the beds may be further traced on Moel-y-Gaer. On the south-east of that hill, the chert, which, as already stated, is there seen resting directly on the limestone, dips W. 37° N. into the hill and under a sandstone on the north-west, which, with large quartz-pebbles and subordinate chert at the top, is well exposed in an old quarry 100 yards north of Foel Farm. The base is not seen. The crest of an anticlinal fold seems to pass through this quarry, for the beds roll over from a south-west dip on the south to a gentle north-east tilt on the north. In another old quarry, north of the last and lower down the hill, both chert and sandstone are exposed with a bed of shale 12 inches thick between. Subordinate chert again occurs near the top of the sandstone.

[1] Op. cit., p. 504.

[2] Cf. W. Hind and J. A. Howe, "The Geological Succession and Palæontology of the Beds between the Millstone Grit and the Limestone Massif of Pendle Hill, and their equivalents in certain other parts of Britain": *Q.J.G.S.*, vol. li, p. 376.

[3] Op. cit., p. 505.

[4] Strahan, op. cit., p. 47.

[5] Strahan, op. cit., p. 51, and B. Smith, op. cit., p. 129.

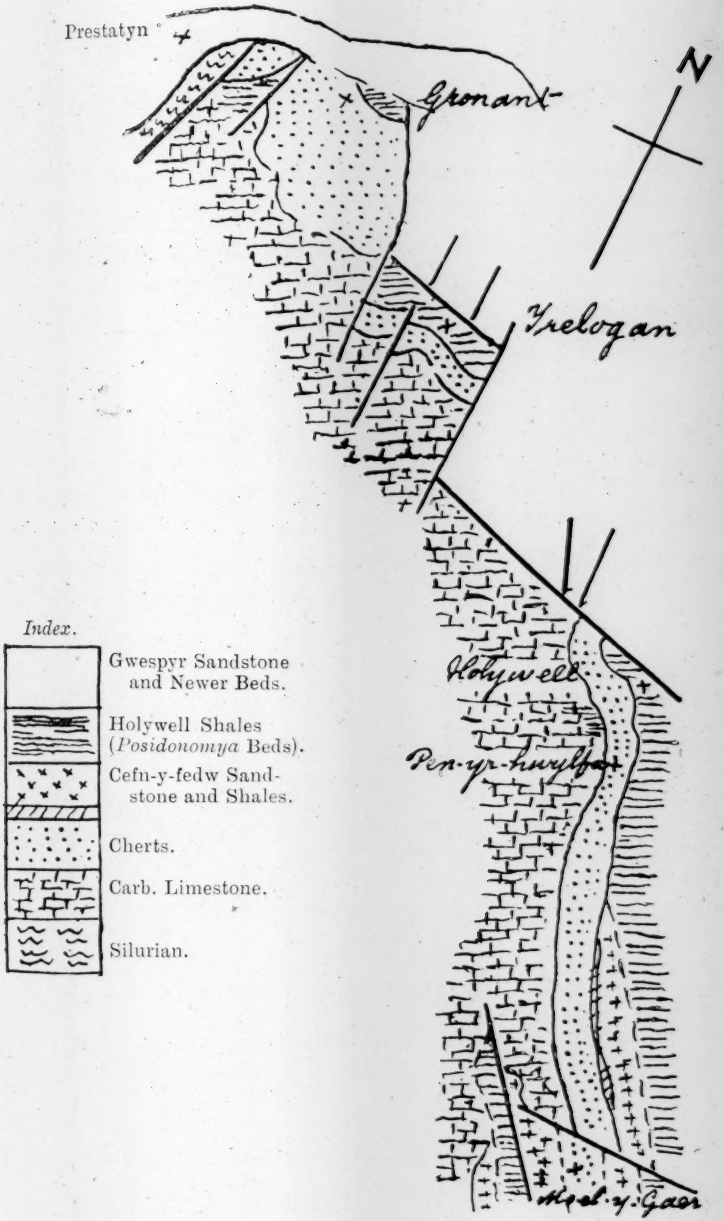

FIG. 1.—Sketch-map of North Flintshire chert-outcrop. Outline mainly taken from Geological Survey maps. Scale, $\frac{1}{2}$ inch = 1 mile.

The beds are somewhat rolling, but the dip is mainly about N. at 21°. The shale is probably the thinned-out representative of the bed already mentioned on the east of Halkyn Mountain.

At Moel Ffagnallt on the west of Moel-y-Gaer, and at Hendre, a mile and a half to the south, the chert has thinned out completely, and the sandstone rests directly on Carboniferous Limestone. In the deep ravine of Nant Ffigillt, north of Hendre, Holywell Shales, with a Pendleside fauna of a higher horizon, as stated by Hind and Stobbs,[1] than that seen further north, are well developed; and a mile or so further south, as shown by Strahan,[2] these beds overlap the sandstone, which has temporarily disappeared, and rest directly on the limestone.

A mile or two further south, strong sandstones resting on the limestone reappear, as at Waen and Gwernymynydd, and these beds rapidly develop southwards into a great series of pebbly sandstones and subordinate cherts.[3]

The sandstone resting on the chert as far north as Pen-yr-hwylfa, possibly further, and traced south in the same position as far as Moel-y-Gaer, is referred to this southern outcrop, which is beyond the scope of this paper.

The evidence of overlap on the west of the outcrop seems equally clear.[4] On the hillside above Prestatyn, thin black limestones and shales with a Pendleside fauna, which at Gronant overlie the cherts, are seen resting with apparent conformity on Carboniferous Limestone. A short distance to the north-east, on the same hillside, south of the Nant Hall Hotel, there is a small exposure of limestones and shales which are quite similar lithologically, and though there is no exposure of chert below, fragments of chert have been brought to the surface by rabbits burrowing. There seems no doubt as to the relationship of the beds. Again, at the famous fossil locality near Teilia Farm, 1½ miles south-east of Prestatyn, the *Posidonomya* beds are resting directly on grey limestone, and they may also be seen dipping off the limestone on the roadside between Holywell and Brynford.

The thickness of the chert-formation varies with remarkable rapidity. In the Talacre Mine, near Gronant, on the northern margin of the outcrop, Morton, from definite information obtained from the manager, estimated the thickness at 250 feet.[5] At Trelogan, about 2 miles south-east of Gronant, Strahan states,[6] on the evidence of mine-shafts and levels, that the thickness can hardly be less than 140 yards. At Grange Quarry, near Holywell, where "Aberdo" limestone can be seen below the chert and Holywell

[1] Op. cit., p. 505.
[2] Op. cit., p. 53.
[3] Cf. B. Smith, op. cit., p. 38.
[4] Cf. Strahan, op. cit., p. 13.
[5] G. H. Morton, "The Carboniferous Limestone and Cefn-y-fedw Sandstone of Flintshire": *Proc. Liverpool Geol. Soc.*, vol. iv, 1885, p. 402.
[6] Op. cit., p. 49.

Shales above, the chert is only about 48 feet thick. On Halkyn Mountain, to the south of Holywell, the thickness again increases, and about 100 feet are exposed in the quarries. The base was formerly seen resting on the limestone,[1] but it now appears to be covered with quarry rubbish. Further south about 3 miles, in the neighbourhood of Moel-y-Gaer, the chert appears to thin out rapidly.

Small, isolated, sharply-folded synclines occur occasionally, as has been noted by other observers. The beds a few feet above are unaffected. Good examples of this feature may be seen in Pen-yr-hwylfa Quarry and in some old quarries on the north side of the road west of Halkyn Hall. In another quarry, nearer Halkyn Hall, on the south side of the road, the structure is seen to be centroclinal. This feature probably results, as suggested by Strahan,[2] from local perishing of the limestone below, causing the chert beds to collapse over a small area.

Thin, discontinuous beds, of a different character from the main mass, sometimes occur. On the top of the chert in Afon Goch Quarry, near Trelogan, a curious bed, about 2 ft. 6 in. thick, in part a cherty conglomerate, in part a gritty chert, is seen. The conglomerate consists mainly of both rounded and angular fragments of chert and quartz. Chert fragments, 2 inches in length, have been noted. In the same quarry, about the middle of the section, there is a bed of white limestone, about 3 feet thick, containing nodules of chert, which show the usual features of chert in that association, such as inclusions of limestone, calcareous organisms sometimes partially replaced, and sponge-spicules. The position of this bed is quite anomalous, but, as the neighbourhood is faulted, it may, perhaps, be the result of a thrust. I have, however, no evidence to offer in support of this suggestion. Lower down in the section, within massive chert there are occasional very short bands or lenticles of white or grey limestone. This is an exceptional feature, so far as my observation goes. It is possible that the beds are near the base of the chert, and that in this locality deposition of the chert began before the termination of the Carboniferous Limestone episode.

In the bank above Trelogan, a bed of calcareous grit, 3 feet thick, was exposed some years ago. This information came from an old miner, who also supplied specimens. The rock contains detrital grains of quartz and muscovite in a paste of calcite.

Strahan [3] records the occasional occurrence of beds of encrinital chert within the massive chert, and he considers them to represent silicified limestone. For reasons which will appear below, I venture to suggest that it is quite possible these organic remains were derived.

[1] Strahan, op. cit., p. 26.
[2] Op. cit., p. 50.
[3] Op. cit., pp. 48 et seq.

The individual beds of chert vary in thickness from an inch, or less, up to 18 or (rarely) 24 inches. They are, as a rule, well and evenly bedded, but, not infrequently, a wavy and concretionary structure may be seen within a massive bed. Good examples of this feature occur in some of the quarries on Halkyn Mountain.

Petrography.

The chert is not uniform in character. There are two main types. On the eastern side of the outcrop a thin-bedded, black, carbinaceous chert, with a vitreous lustre, predominates. Over the remainder of the outcrop the rock, as a rule more massive than the other, is generally blue or brown of varying shades, sometimes nearly white. Iron predominates over carbon in this type (see analyses), and appears to be the pigmenting agent. It may, for convenience, be called the ferriferous type. Analyses of the blue chert show it to contain iron in the ferrous state only. The brown and other shades are probably the result of oxidation or weathering. Both types often present a banded appearance, which the microscope shows to result from segregation of iron or other impurities, apparently always parallel to the bedding.

In the Pentre Quarries, near Gronant, on the north-east of the outcrop, about 100 feet of black, carbonaceous rock are exposed. It consists of very even beds, varying in thickness from 1 to 8 or (rarely) 12 inches. Each bed has an upper and lower margin of a black siliceous limestone or bastard chert, with a granular aspect, and an inner layer of black chert with a vitreous lustre. The upper and under surfaces of these inner layers of chert are usually parallel to the bedding planes, but sometimes the under surfaces are lumpy and irregular, and, occasionally, the chert occurs in nodules and small lenticles instead of extended sheets. The uppermost 10 feet of the rock exposed in the northern quarry consist of beds of the siliceous limestone without an inner layer of chert, and occasionally similar beds may be seen in the mass of the rock below.

South of Gronant the black, carbonaceous chert is seen in the old tramway cutting at Grange Quarry, about a mile north-west of Holywell, and near Coed-y-fron, about half a mile south of Holywell. The chert at these exposures is thin-bedded, as at Gronant, but, unlike that rock, it appears to be chert throughout. At Grange Quarry the beds are wavy and irregular, possibly the result of ripple-forming currents during deposition.

The so-called shale-partings which sometimes occur between the beds of chert, appear, in the specimens I have examined, to be merely thin, laminated beds of an impure or bastard chert, with a granular aspect, and often showing fluidal arrangement. A thin section of one of these partings in the quarries near Gronant contains many fragments of detrital limestone and chert, their longer axes parallel to the bedding, in a base of non-clastic cherty silica

(Pl. VI, Fig. 2). Another thin section of a parting in the chert near Coed-y-fron shows much detrital quartz and muscovite in a similar base. As a rule, there is merely a divisional plane between the beds without intercalated terrigenous material. This is true of both the thin-bedded black cherts and the blue and brown usually more massive rock.

In the blue and brown cherts (the ferriferous type), carbonaceous matter is sometimes absent or only present in very minute quantity (Analyses II, III, V, and VI). When it occurs in larger quantity (Analysis IV) it appears to be aggregated into small flakes and clots, which do not affect the general colour of the rock.

The absence of carbon dioxide from the ferriferous type is very noteworthy (Analyses II to VI). In general, the mass of the rock appears to be quite free from calcium carbonate, except in the exceptional occurrences noted above, and in some beds at the base immediately above the limestone. Here, there may be inclusions of limestone and calcareous organisms, and the features may resemble those of the chert on a lower horizon within the limestone.

A further noteworthy feature of the ferriferous type of these cherts is the abundance of detrital material frequently seen in thin sections (Pl. VI, Fig. 1). It consists chiefly of rounded and angular grains of quartz, usually isolated in the ground-mass, but they are sometimes so numerous as to give parts of a section almost the appearance of a grit, with a cement of cherty silica. Muscovite, zircons, and magnetite are common, and a little biotite and an occasional grain of tourmaline also occur. This detrital material is very sporadic in distribution; it is not found throughout the entire thickness of the beds, nor is it confined to any one horizon. The grains, which are always ungraded, appear to be most abundant in the north, where the coarsest material is generally seen. On the hillside above Prestatyn they occur up to 1·62 mm. in length. The chert at the base of Trelogan Quarry contains very numerous grains, but smaller in size, the largest being about 0·576 mm. long. Fragments of limestone, which have every appearance of being detrital, are associated here with the quartz grains.

Traced further south, this detrital material diminishes, generally, in both size and quantity, till, in thin sections prepared from the rock on the south-east side of Moel-y-Gaer, it is seen to be of silt-grade (0·02 mm. and less) and much lessened in amount. Further west, however, on nearly the same latitude, in the quarry above referred to, on the north-west side of Moel-y-Gaer, coarser material again appears in the bed immediately below the shales. It seems possible that material from the south may have been intermingled here with the silica of the chert-deposit.

A grain or two of felspar sometimes occurs among the quartz-grains, and clayey matter is often much in evidence, especially in the southern part of the outcrop. It is present either in small clots or in streaks traversing thin sections. Viewed by transmitted

light, this material is black or brown, but by reflected light it is white, and is thus easily distinguished from carbonaceous or iron impurity (Pl. VI, Figs. 3 and 6).

On the east of the outcrop, in the neighbourhood of Gronant, except in the thin partings showing flow-structure, mentioned above, there is very little detrital material present, and that only of very minute size. It is evident that quiet sedimentation was the rule here, although there were sometimes brief interruptions by current action.

The blue rock generally has a more or less vitreous lustre; the brown often resembles a fine-grained sandstone.

Under the microscope all these cherts are seen to be stained, in greater or less degree, with carbonaceous, or ferruginous, or clayey impurity. The ground presents the usual gradations in crystallization of gelatinous silica, from isotropic through cryptoto microcrystalline, often with beautiful spherulitic structure. Fibrous chalcedony is often developed and (rarely), in small areas free from impurity, granular quartz. The birefringent spots in microcrystalline areas vary greatly in size, being larger when little impurity is present, and sometimes impinging on each other so as to resemble a quartz-mosaic. The birefringence is lower than that of quartz, and the extinction is wavy, presumably due to molecular strain. But although crystallization always appears to be arrested by carbonaceous or iron impurity, the silica is sometimes seen to remain very feebly cryptocrystalline or isotropic, although apparently free from impurity.

In the chert and associated siliceous limestone which occurs in the neighbourhood of Gronant, rhombs of dolomite or calcite, characteristic of chert associated with limestone, are abundant. They have not been noted in any other part of the outcrop. Crystals of pyrites also occur in the Gronant beds and the other black carbonaceous chert on the eastern side of the outcrop, and occasionally small, metallic-white grains, probably mispickel, may be seen.

Carbonized plant-fragments are not uncommon, but other megascopic organic remains, except in the thin encrinital beds, are, as already noted, very scarce. On the other hand, although most thin sections appear to be quite barren, the microscope not infrequently shows broken fragments of calcareous organisms, always, so far as I have seen, entirely silicified. Chief among these are long, thin, often slightly curved, tube-like structures and cross-sections of the same, their diameter ranging from 0·015 mm. to 0·05 mm. (Pl. VI, Fig. 6). Their interior is usually filled with chalcedony, often showing agate-structure. Dr. W. D. Lang and Miss Wood, of the Geological Department of the British Museum, have kindly examined these structures, and consider them to be spines of *Productus*.

A thin section of the chert at Moel-y-Gaer shows a crowded

medley of water-worn fragments of Echinoderms, Foraminifera, and Polyzoa. Very occasionally, in a few thin sections, small circular areas of crystalline silica, entirely devoid of structure, may be seen. I hesitate to call them Radiolaria, although they strongly resemble some of the structures so named in the Lower Culm cherts of Devon. Broken crinoid ossicles occur occasionally, and there are often obscure markings, the nature of which, whether organic or not, it is difficult to determine.

Sponge-spicules, which Dr. Lang refers to the genus *Hyalostelia*, occur in one or two thin sections from the neighbourhood of Moel-y-Gaer. They appear to be associated with the spines of *Productus*. Distinction between the two is not always easy, when, as is often the case here, they are broken into short fragments. There is, however, nothing in the slides I have examined to support Hind and Stobbs' statement[1] as to the abundance of sponge-spicules in these cherts.

In view of the fragmental and often water-worn character of these remains, and their promiscuous assemblage when they occur, it seems clear that they are derived fossils, washed in like the other detrital material. It may be noted that broken crinoid stems occur in the *sandstone* overlying the chert at Moel-y-Gaer.

ANALYSES.

By H. F. Harwood, Ph.D., M.Sc.

	I	II	III	IV	V	VI
SiO_2 .			97·33		97·83	94·45
Al_2O_3.			0·48		0·36	2·42
FeO .		0·22	0·16		0·10	none
Fe_2O_3	0·27	none	none	0·28		0·28
C. .	0·60	none	0·04	0·21	0·02	0·08
CO_2 .	2·72	none	none	none	none	none

I. Black carbonaceous chert, Pentre Quarry, Gronant.
II. Blue chert, Afon Goch Quarry, Trelogan.
III. Blue chert, Pen-yr-hwylfa Quarry, Halkyn Mountain.
IV. Whitish band in blue chert, Pen-yr-hwylfa Quarry, Halkyn Mountain.
V. Grey margin on blue chert, Pen-yr-hwylfa Quarry, Halkyn Mountain.
VI. Pale brown chert, Quarry near Terfyn, Prestatyn.

These partial analyses have been made mainly with a view to throwing light on the colour-problem. It will be noted that in the blue rock (Nos. II and III) iron is present in the ferrous state only. Dr. Harwood suggests that there may be some ferrous compound present, a silicate perhaps, which imparts a strong bluish tint even when present in small amount.

Carbonaceous matter appears to be the colouring agent of the black chert (No. I).

In Nos. IV and VI the iron has obviously been oxidized. In No. V, Dr. Harwood states that it is probably mainly ferrous.

[1] Op. cit., p. 500.

The absence of carbon dioxide in all but the black Gronant chert is noteworthy as showing the absence of carbonates.

Theoretical Considerations.

Variations in Thickness of the Formation.—This striking feature is believed to have resulted from contemporaneous erosion of the underlying limestone. There is clear evidence of this in the presence of detrital fragments of limestone in thin sections (Pl. VI, Figs. 2 and 3). The unconformity at Waenbrodlas noted by Hind and Stobbs [1] is additional evidence. Morton [2] also has recorded two instances of denuded surfaces in his "Upper Black Limestone", and Strahan [3] has noted several instances of the perishing of the limestone, probably from solution by underground waters. It has also been pointed out above that the small, isolated synclines sometimes seen in the chert are probably due to the same cause.

The Gronant Beds.—The chert in the Pentre Quarries at Gronant, and elsewhere in the neighbourhood on the north-east of the outcrop, is intimately associated, as noted above, with a very siliceous, black limestone or bastard chert. The association strikingly resembles that sometimes seen in Derbyshire,[4] as at the Black Marble Quarry near Ashford, and at Knivetonwood. There would seem to be little doubt that calcium carbonate and colloidal silica were simultaneously precipitated and that segregation of the latter took place to a large extent to form the chert layers. The percentage of insoluble material in the bastard chert was ascertained by boiling powdered material in acid. In a specimen from a bed without an inner layer of true chert, and in which, therefore, for some obscure reason, no segregation had taken place, there was 63·6 per cent of insoluble residue. In a specimen from another bed which contained an inner layer of true chert, the insoluble residue in the bastard portion was 48·7 per cent. In each case the residue consisted mainly of cherty silica with much carbonaceous impurity. This determination is confirmed by the thin sections. It is significant that this part of the outcrop is nearest to the source, in the direction of Pendle Hill in Lancashire, from which the overlying *Posidonomya* beds were in all probability derived. It seems equally probable that the limestone interbedded with these Gronant cherts came from the same source.

The Replacement-theory of Chert-formation.—On the other hand, in the beds which form by far the greater part of the outcrop, and have been called for convenience the ferriferous type, calcium carbonate, either in the form of limestone or calcareous organisms,

[1] Op. cit., p. 396, and pl. xxii.
[2] Op. cit., p. 400.
[3] Op. cit., pp. 41–4.
[4] Cf. H. C. Sargent, "The Lower Carboniferous Chert Formations of Derbyshire": Geol. Mag., Vol. LVIII, 1921, p. 274.

appears to be entirely absent except at the base in proximity to the Carboniferous Limestone and in the instances, noted above, where it occurs as detrital material or anomalous beds. If hundreds of feet of limestone had been replaced, assuredly abundant megascopic vestiges of the fauna would have everywhere remained to tell the tale. It may be pointed out that the presence of subordinate beds of chert, within the sandstone of the southern outcrop, is clear evidence that replacement of limestone is not a necessary factor in the formation of chert. Concretions of chert are also not uncommon in the ganister (a fine-grained quartz-sandstone with a siliceous cement) of the Lower Coal Measures in South Derbyshire. Clearly, no replacement has taken place here.

The Sponge-spicule Theory of Chert-formation.—The theory of derivation from solution of sponge-spicules seems equally helpless here. An argillaceous medium is necessary for sponge-life, and although, as already stated, some beds contain a small admixture of clayey impurity, the greater proportion appears to be free. Apart from the evidence given in a former paper,[1] it is unthinkable that the countless generations of sponges necessary to form these thick beds could have flourished on a pure siliceous deposit. The absence of their remains from most thin sections appears conclusive of their absence from the sea-floor when the chert was laid down.

The Source of the Silica.—Strahan, rejecting the sponge-spicule theory advocated by G. J. Hinde, considered [2] that "the deposit as a whole may be regarded as a very fine siliceous sediment, hardened by a siliceous cement". It is, however, obvious under the microscope that the rock is essentially non-clastic in character, and the gradations in its crystallization clearly indicate derivation from gelatinous silica. Since it appears from the foregoing considerations that organic silica must be ruled out, we are compelled to seek an inorganic origin.

The occurrence of this thick formation on one definite horizon throughout the entire outcrop, apart from the considerations under the head of "The Replacement-theory", is conclusive evidence against the action of percolating ground-waters.

For the same and other evident reasons it seems impossible to invoke a magmatic source, and the only alternative appears to be that the silica was brought down in solution by rivers and precipitated on the sea-floor. This view is strongly supported by the presence of detrital quartz and other minerals in the chert, with which they are clearly contemporaneous. It is suggested that an adjacent land-surface, possibly a peneplain, while mainly undergoing chemical decomposition, was occasionally subjected to mechanical erosion, the products of the two processes being thus, from time to time, brought down simultaneously.

[1] H. C. Sargent, op. cit., which see for a fuller discussion of the problems considered in this and the following sections.

[2] Op. cit., p. 47.

The objection may perhaps arise that still water would presumably be required for precipitation of dissolved silica. It may be recalled, however, that there is clear evidence in Derbyshire of contemporaneous beds of chert in current-bedded limestone.[1] The presence of plant-remains and the fluidal arrangement in some of these beds, as noted above, also indicate current-action.

The Direction of Transport.—It is believed that the land-surface from which the silica was derived, lay to the north. This view is supported by the diminishing quantity and size of the coarser detrital material, and the increase of clayey matter in the chert, as it is traced south. It should also be remembered that the great mass of the chert lies in the northern part of the outcrop, and that it thins out southwards. The passage-beds below the chert and the Carboniferous Limestone itself also thin out in the same direction.

It is very interesting to note that there is a thick bed of chert at Red Wharf Bay, in Anglesey,[2] and another in the Trough of Bowland, in Lancashire, both on precisely the same horizon as the North Flintshire formation. The topographical relation of these three contemporaneous beds to each other suggests that they were probably all fed from the same land-surface. It has, further, been shown by Dr. Greenly [3] that there must be extensive beds of chert on the floor of the Irish Sea to the north-east and north of Anglesey. Mr. G. H. Hodgson has found pebbles of banded chert, lithologically similar to that of North Flintshire, on the beach at Penmaenmawr, and boulders in the drift at the same place.

The Problem of Precipitation.—This problem is somewhat obscure. It has been shown by Murray and Irvine [4] that organisms, when present, do not play an important part in the precipitation of silica. Diatoms and Radiolaria obtain their silica from suspended clay, and sponges probably from the clay in which they grow on the sea-floor. It has been proved by experiment [5] that calcium bicarbonate is an important precipitant of colloidal silica in solution. This is held to explain the occurrence of chert associated with limestone. In the case of chert without such association, this view will not hold good.

The electrolytes present in normal sea-water are known to be comparatively ineffective in the flocculation of colloidal silica. Murray and Irvine [6] are of opinion that if the sea receives the greater part of its silicic acid from rivers in the form of soluble silicates, such silicates would be decomposed by magnesium salts, so

[1] H. C. Sargent, op. cit., p. 267.

[2] Cf. E. Greenly, "The Geology of Anglesey": *Mem. Geol. Surv.*, 1919, p. 604.

[3] Ibid., p. 715.

[4] "On Silica and the Siliceous Remains of Organisms in Modern Seas": *Proc. Roy. Soc. Edin.*, vol. xviii, 1891, pp. 229–50.

[5] Cf. W. A. Tarr, "Origin of the Chert in the Burlington Limestone": *Amer. Journ. Sci.*, vol. xliv, 1917, p. 436. Also R. S. Dean, ibid., vol. xlv, 1918, p. 413.

[6] Op. cit., p. 237.

abundantly present in sea-water, with formation of magnesium silicate, which, even in the amorphous state, is nearly insoluble. Davis [1] supports this view.

There are, however, other possibilities. Davis [2] makes a suggestion which is worth considering here. If we may conceive of humid, tropical weathering of granitic rocks, with rather shallow, enclosed basins along the margin of the land, diffusion being thus largely prevented, the continued accession of waters rich in silica and poor in lime and magnesia would produce important modifications. When such magnesia as was present was used up in combination with silica, waters would be produced, rich in alkaline chlorides, which would precipitate silicic acid. Such waters would probably be unsuitable for organic life. It is to be noted here that the assemblage of detrital minerals in these cherts clearly indicates that a granitic land-surface was undergoing disintegration.

Another reaction that may quite possibly have taken place, in combination with the foregoing, may be mentioned. The silica resulting from decomposition of granitic rocks would probably come down in the form of colloidal alkaline silicates. It has been proved experimentally [3] that such silicates are easily decomposed, with flocculation of colloidal silicic acid, by ammonium carbonate. It has been shown by Murray and Irvine [4] that ammonium salts exist everywhere in the ocean, owing to the decomposition of organic matter, and it is perhaps to this circumstance that the small percentage of organic carbon present in the ferriferous type of these cherts is due.

It appears evident, however, that a more or less landlocked basin would be necessary to prevent rapid diffusion of the solutions, and it is worth while to consider for a moment whether, without stressing the evidence unduly, such a condition may be reasonably postulated in the present case.

The ungraded character of the detrital material in these cherts seems clearly to indicate a sudden check to the currents by which the sediments were brought down.

On the west of the outcrop, Strahan [5] considers that the thinning out of the Lower Carboniferous beds was due to the neighbourhood of a coast-line.

The same view, for the same reason as regards the chert, applies to the south. There, too, the rapidly increasing coarseness of the overlying sandstone bears in the same direction.

On the north, the probable proximity of a peneplain land-surface

[1] E. F. Davis, "The Radiolarian Cherts of the Franciscan Group": *Univ. Cal. Pub. Geol.*, vol. xi, 1918, p. 382.
[2] Ibid., p. 383.
[3] Davis, op. cit., pp. 399–400.
[4] "The Coral Reefs and other Carbonate of Lime Formations in Modern Seas": *Proc. Roy. Soc. Edin.*, vol. xvii, 1889, p. 92.
[5] Op. cit., p. 13.

has been shown, though it probably lay at some distance from the present northern margin of the Flintshire outcrop.

On the north-east, the direction from which the black, carbonaceous limestone associated with the Gronant chert was derived, it has been shown that quiet sedimentation was probably the rule, and, bearing in mind the chemical reaction between calcium bicarbonate and colloidal silica in solution, precipitation would no doubt be rapid, and would take place near the shore-line, diffusion being thus prevented.

The presence of plant-remains in the chert also indicates neighbouring land.

It is thought, therefore, that we have fair evidence of conditions tending to prevent diffusion and facilitate precipitation of silica in solution, in the area covered by these cherts. It should be noted further that under these conditions the water of the basin would probably tend to be brackish, and this, apart from chemical considerations, would be unfavourable to the life of marine organisms.

The variation in the thickness of individual beds of chert, ranging from an inch or less up to 18 and sometimes 24 inches, may be explained as the result of the varying time required to produce supersaturation of the colloidal material. After precipitation there would necessarily be a pause of varying length, according to the rate of decomposition of the adjacent land-surface, until supersaturation was once more reached. It has already been explained that the beds are generally separated by simple bedding-planes, free from extraneous terrigenous material.

Conclusion.

The evidence afforded by the field-relations and petrography of the massive chert-formation of North Flintshire appears clearly to indicate that it is an original chemical sediment of inorganic origin.

Chert, other than that of magmatic origin, is probably always a shallow-water or off-shore deposit, and in this case it is believed to have been laid down in a largely land-locked basin which was undergoing gradual subsidence. Towards the close of the episode, elevation set in. This is shown by the seaward overlaps[1] on the west and south and by the higher horizon of the fauna of the overlapping *Posidonomya* beds in the south, as compared with the fauna of the same beds in the north.

The silica is believed to have been derived from disintegration of a granitic land-surface lying somewhere in the north, from which it appears possible that contemporaneous beds on the west and east were also supplied.

The process of precipitation cannot be stated with certainty, but chemical reactions have been indicated which are believed to be within the range of likelihood.

[1] Cf. P. G. H. Boswell, "Sedimentation, Environment, and Evolution in Past Ages": Pres. Add., *Trans. Liverpool Biol. Soc.*, vol. xxxv, 1921, p. 9.

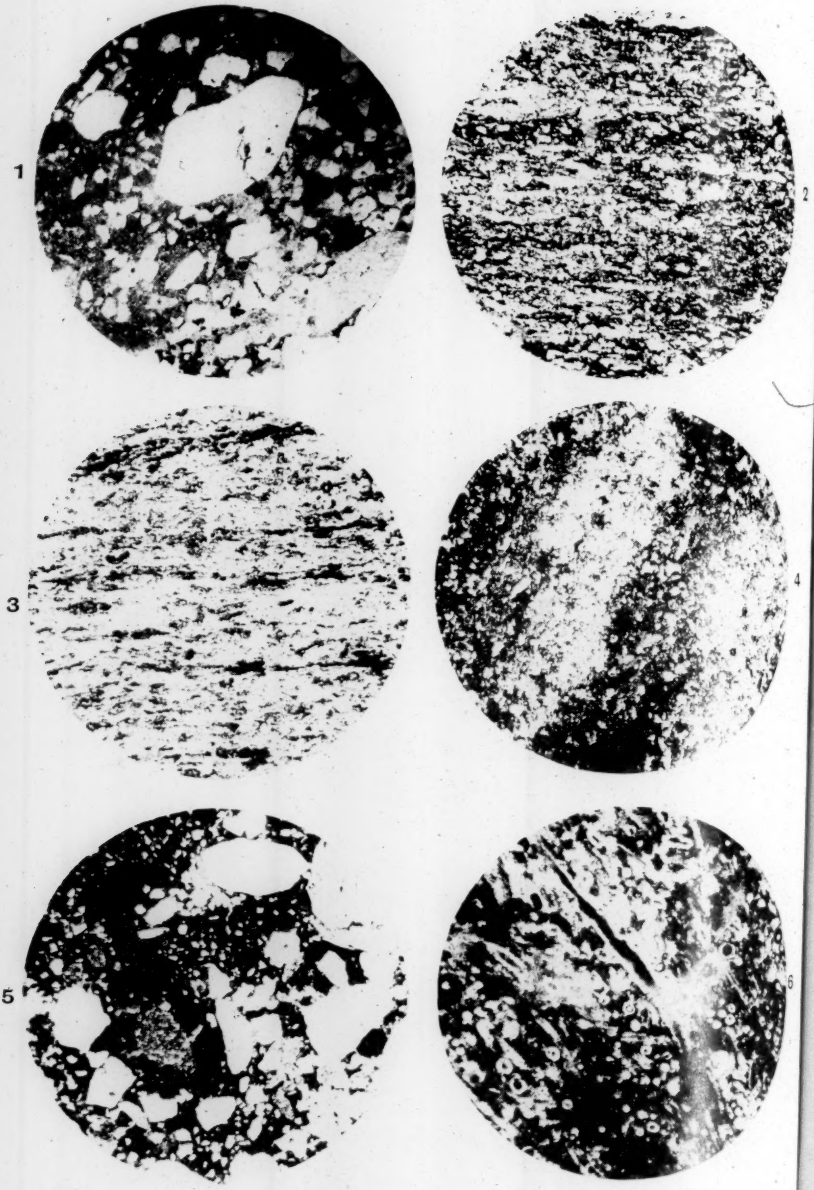

Photo *G. S. Sweeting.*

MICROSCOPE SECTIONS OF FLINTSHIRE CHERTS.

To face p. 173.

The absence of organic remains, other than fragments sporadically distributed and believed to be derived, tends to show that conditions during the chert episode, possibly due to chemical reactions in the sea-water, were unfavourable to life.

I have to thank many friends for generous assistance during this investigation: Dr. H. F. Harwood, for the interest he has taken in the analyses; Dr. W. D. Lang, for determination of organic remains; Professor W. T. Gordon, for much discussion of petrological problems; Mr. E. Montag, for valuable help in the field; Mr. T. A. Jones, of the Liverpool Geological Society, for the loan of their sections and discussion of their contents.

I have also to acknowledge my great indebtedness to Sir A. Strahan's Survey Memoirs, from which I have drawn much valuable information, although I have ventured to differ from some of his conclusions.

EXPLANATION OF PLATE VI.

Fig. 1.—Gritty chert (ferriferous type), Hillside south-east of Prestatyn. Ordinary light, +15 diams. (slide 635). The section consists of pale brown, ironstained, cryptocrystalline silica, with abundant inclusions of rounded and angular ungraded grains of quartz. No organisms present.

Fig. 2.—Parting between chert-beds, Pentre Quarry, Gronant. Ordinary light, +28 diams. (slide 659). The section contains abundant current-bedded, detrital fragments of limestone, and a few of quartz and chert, in a base of cryptocrystalline silica, stained by carbonaceous matter.

Fig. 3.—Chert, base of beds, Trelogan Quarry. Ordinary light, +28 diams. (slide 612). The section consists of current-bedded, detrital fragments of limestone in a base of cryptocrystalline silica, with streaks of clayey matter parallel to the bedding.

Fig. 4.—Blue chert, Pen-yr-hwylfa Quarry, Halkyn Mountain. Ordinary light, +15 diams. (slide 676). Irregular bands of iron impurity traverse the section in a base of cherty silica. The crystallization of the silica is more fully developed between the bands than within them.

Fig. 5.—Sandstone resting on chert, Pen-yr-hwylfa Quarry, Halkyn Mountain. Nicols crossed, +15 diams. (slide 671). The section consists of ungraded, detrital material, mainly quartz, with chert, muscovite, and zircons. The grey, microcrystalline grains are chert.

Fig. 6.—Clayey Chert, Quarry on south-east side of Moel-y-Gaer. Ordinary light, +35 diams. (slide 668). The ground of this section is microcrystalline silica much impregnated with clayey impurity. It is crowded with silicified spines of Productus, in both longitudinal and cross-sections. Their interior is often filled with chalcedony.

REVIEWS.

GEOMORPHOLOGY OF NEW ZEALAND. PART I. SYSTEMATIC. AN INTRODUCTION TO THE STUDY OF LAND FORMS. By C. A. COTTON, D.Sc., F.G.S., Professor of Geology, Victoria University College, Wellington. pp. i–x, 1–462, with 442 figures. Wellington, N.Z. Dominion Museum, 1922.

THE author in his preface acknowledges his debt "to all the pioneers in geomorphology, and most of all to that great teacher, Professor W. M. Davis, of Harvard University". One is therefore prepared for the use of the modern nomenclature initiated by the American geomorphologists, and it is used without stint. The time has perhaps passed when the die-hards of the old school objected to its use, and it has come to stay. One cannot help feeling, however, that it is not yet stabilized, the irregularities of juvenility have yet to be replaced by the smoothness of maturity. One is sometimes at a loss to know the exact sense in which certain terms are used by the author. As the object of the nomenclature is precision, it is perhaps surprising to find the frequent use of the terms uplift and depression. The author, it is true, refers to negative and positive movements, but often uses the word uplift when it is doubtful whether the movement referred to was true uplift. One might raise objections in the case of many other matters of detail, and the author will probably make many small alterations in a future edition; but it would be ungracious to lay stress on minor defects in work of such outstanding excellence, and the small blemishes but serve to bring into relief the admirable character of the book as a whole.

The work is one of the manuals of the New Zealand Board of Science and Art, and is "cast in the form of a textbook of geomorphology for New Zealand students and general readers". It is, however, much more than that. It can be strongly recommended for use by students of any country, and is the most complete textbook of the kind in the English language which has come to my notice. So favoured is New Zealand, that examples of the operation of all the important physiographical agents are supplied, and are here fully expounded.

More than half of the book is devoted to water-action. This is not excessive, partly on account of the complexity of the subject, but mainly because the problems connected therewith have been so much more fully studied than those bearing upon other agencies. There are adequate accounts of the operations of wind, glaciation, volcanoes, and marine agents. The importance of the study of the cycle is very fully realized and explained.

Chapter XIV on Block Mountains, is of great interest, and the author shows how many mountains, even when largely built up of highly disturbed rocks, owe their present eminence to block-structure and not to folding.

Chapter XVII, on composite topography of river-terraces, may advantageously be read (together with Professor W. M. Davis' papers of the subject) by students of Pleistocene river-deposits.

But one need not particularize further; elementary and advanced readers alike will profit by perusal of the work, which is very fully illustrated. Certain illustrations are somewhat obscure, but many are excellent, and the extensive use of block-diagrams is an important and welcome feature.

J. E. M.

EXCAVATIONS AT ABU SHAHRAIN (ERIDU) MESOPOTAMIA. Proc. Soc. Antiq., 1919. pp. 72–8. Archæologia, vol. lxx, 1920. pp. 101–44.

CAPTAIN R. CAMPBELL THOMPSON conducted excavations on this important site just after the war, and the bulk of his work does not concern geologists. But he carefully collected the shells found at depths of 4, 6, and 12 feet, and Mr. R. Bullen Newton reports upon them as follows: *Unio* cf. *tumidus*, *Melania tuberculata*, *Anodonta rhomboidea* associated with *Alectryonia* cf. *cucullata* and fragments of *Strombus*. His conclusions we give in Mr. Newton's own words, the importance of which will be found in the last paragraph.

"Numerous examples of *Melania tuberculata* were also collected from the desert surface of Abu Shahrain, this species being similarly abundant over certain regions of Northern Africa, Madagascar, India, etc. The deposits containing these specimens were of a fine silty-alluvium character, and undoubtedly of fluviatile origin, resulting from the overflowing of the River Euphrates at different periods, on account of the presence of freshwater shells which exist in that river at the present day. The association of such shells with shells of marine habit, a pig's tooth, and a flint flake, etc., would, in my opinion, suggest that the site where they were found was once occupied by a primitive race, the soft animal parts of the shells as well as pig's flesh forming part of the food of those early races. It is suggested that the *Strombus* and oyster remains were introduced from the Persian Gulf, since they now occur living in those waters. It may be noted that only the basal parts of the *Strombus*-shell were found, having apparently been fractured for the extraction of soft parts as a food. As the upper or spiral portions are entirely missing, it is assumed that they may have been used for bartering or other purposes. It is quite possible that the *Strombus*-animal was then used as food, since that mollusc is still to be seen on sale in the Suez market at the present day. So far as Captain Thompson's specimens are concerned there is no evidence that the sea ever reached this particular district of Mesopotamia, Abu Shahrain being a considerable distance from the present littoral margin of the Persian Gulf, although it has long since been proved that a former littoral margin can be traced more than 250 miles inland in a north-

westerly direction between Warka and Korna, and within a short distance of the alluvial plains that stretch away to Abu Shahrain and beyond. For such information we are indebted to the researches of W. Anderson and Loftus, who reported the occurrence of recent marine deposits at Warka, Korna, and other neighbouring localities containing species of shells more or less identical with those now living in the Persian Gulf, which they interpreted as marking a former margin of the Persian Gulf. These geological results seem to negative the old idea that this Babylonian site, known afterwards as *Eridu* and later as Abu Shahrain, was ever a marine port."

THE PRETORIA SALT-PAN, A SODA CALDERA. By P. A. WAGNER. Geol. Survey of the Union of South Africa, Memoir 20, pp. 136, with xix plates and 6 text-figures. Pretoria, 1922. Price 7*s.* 6*d.*

THE remarkable structure described in this memoir has long been known to geologists, and has also been worked commercially, though not very successfully, as a source of soda compounds. In form it is a typical crater, with a rim on the average about 100 feet above the surrounding country, while the centre of the floor, about 300 feet below the top of the rim, is normally occupied by a salt lake, which lies about 3,480 feet above sea-level, and in old days was a well-known salt-lick for the vast herds of game which then inhabited this region.

There is no doubt that this basin is a caldera, whose history can be summarized as follows, in three stages: Firstly, updoming of the granite country rock; secondly, drilling of the vent by a tremendous explosion; thirdly, subsidence by faulting, down-folding, and slumping of the interior within a ring-shaped fault. The last-named phenomenon presents some analogy to the cauldron-subsidence of Glencoe, but was obviously quite a superficial phenomenon. The crater wall consists mainly of fragmental material, only the lower part of the inner slope being rock in situ. The ejected blocks include some interesting rock-types, of which the most remarkable is a dolomitic breccia; this appears to consist of fragments of schist and quartz embedded in a magmatic dolomite-calcite-biotite-pyrite-apatite rock, analogous to some of the magmatic carbonate rocks recently described by Brögger from the Fen district in Norway.

The salt-deposits of the central area include, besides common salt, also, extensive masses of trona and gaylussite. The most important product economically is the soda-salt liquor pumped from the gaylussite layer. The physical chemistry of this solution is discussed in detail in the memoir.

It is impossible here to mention all the interesting features shown by this remarkable phenomenon. The memoir will well repay reading by all geologists, both theoretical and economic.

SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY FOR 1921. pp. iv+189, Figs. 6. Price 5*s*.

THE report on the work of the Geological Survey in 1921 published at the end of last year includes the first reports of the work of revision of the mapping of the Northern Coalfields of England, and these reveal many facts of great practical importance in the coal-mining operations. Amongst these may be noted the recognition of the fact that the Scremerston coals of the Northumberland field undoubtedly improve both in thickness and quality when traced in a northerly direction; they may thus constitute an important reserve of coal concealed beneath the covering fringe of higher beds along the Berwick coast. In the West Midland District the extent of the Upper Red Measures and their relation to the Productive Coal Measures beneath has rightly claimed a large share of attention; on palæobotanical grounds, however, it should be noted, Dr. Kidston shows that only the highest beds of those classed as Upper Coal Measures by the British Geological Survey are the equivalent of the Upper Coal Measures of the Continent.

In the same district further work has thrown light on the somewhat complex structure of the Silurian inliers lying on the margin of the Shrewsbury and South Staffordshire coalfields.

In the London district the most interesting results are those relating to the overlap of the Lower Tertiaries and the nature of the underlying surface upon which the Eocene beds were laid down.

In Scotland progress has been made in determining more definitely the Coal Measure sequence in the Stirling and Alloa Coalfield, whilst the complicated structure of the concealed coalfield of Central Ayrshire has become increasingly evident.

In the Highlands the most noteworthy work appears to be that relating to the complex nature of the Tertiary volcanic rocks of Ardnamurchan, which have not yet been completely surveyed, though enough is now known to show that they have many points in common with the central area of igneous rocks in Mull.

Some of the work of the most general interest is as usual contained in the various appendices. Pre-eminent amongst these is Dixon's masterly account of the difficult Glacial Geology of North Cumberland, resulting from the mutual relations between the local ice on the one hand and the Irish Sea ice on the other. At a late stage in the Glacial history of the region, temporary lakes appear to have been held up by dams of ice, recalling in some respects those made familiar to us by the researches of Kendall in the Cleveland Hills; the existence of these lakes is largely inferred from the occurrence of fans of deposit laid down by streams entering them from the hills on either side.

Another valuable appendix is by Kidston, and deals with the fossil plants of the Northumberland and Durham Coalfield. In this he shows that sufficient evidence has now been obtained to determine definitely the age of the greater portion of the coal-bearing strata as Westphalian.

These annual reports are of great value, and it is therefore to be deplored that the steady increase of price, which has now reached the verge of prohibitiveness, must limit their sale among those whose interest in the work of the Survey it is desirable to stimulate. Our Treasury might well take a lesson from other nations both in Europe and America in this respect.

G. L. E.

GEOLOGY. Science for All Series. By C. I. GARDINER. pp. vii+138, 74 figures. Murray.

THIS volume of the Science for All Series gives a good idea of the scope of the science of geology. The subject-matter is divided into three sections: Pt. I. The Earth's Surface. Pt. II. The More Important Minerals and Rocks of the Earth's Crust. Pt. III. Stratigraphical Geology. In all of these the treatment is concise, clear, and well arranged, though, perhaps, Pt. I is the least successful of the three, for here one notices one or two statements that are misleading. After an historical introduction, in which one misses the name of Lyell, the processes of deformation and degradation are dealt with; here it seems a pity not to use the terms tensional and compressional with regard to the types of fault described, and the association of reversed faulting with horizontal beds, as in fig. 4, is apt to convey a wrong idea of the facts; also the definition of the thickness of the bed would be better described as the least distance between the upper and lower *surfaces*.

For the rest, the figures are for the most part clear, though one regrets the continued use of old blocks, presumably to save expense, when a modern photograph would have been more convincing.

G. L. E.

THE AVERAGE CHEMICAL COMPOSITION OF IGNEOUS ROCKS. By F. W. CLARKE and H. S. WASHINGTON. Proc. Nat. Acad. Sci., vol. viii, 1922, pp. 108–15.

THE authors have recently completed computations of the average chemical composition of the rocks of various countries, of the continents, and of the whole earth's crust, to be published as a *Professional Paper* of the U.S. Geological Survey. In this short paper are contained various summaries of the results attained, for the use of geologists pending the appearance of the detailed work. The data used were 5159 "superior" analyses, published between 1884 and 1913 inclusive. The average silica-percentage for the whole earth works out to 59·12, for Europe 59·84 (from 1985 analyses) and for North America 60·19 (from 1709 analyses). Hence the variation is not very great. Figures are also given, in elements, for a ten-mile and twenty-mile crust; in the case of the ten-mile crust separate figures are given for igneous rocks alone, and for igneous and sedimentary together; the difference is negligible, usually

appearing only in the second decimal place. The inclusion of the sediments, however, multiplies the percentage of carbon by three, a not unexpected result. It is, however, rather surprising to find that cerium and yttrium together come to 0·02 per cent, and vanadium to 0·04 per cent in the whole crust.

A Contribution to the Geology of New Guinea. By Evan R. Stanley. Bulletin of the Territory of Papua, No. 7, 1921. Home and Territories Dept., Melbourne, or direct from the Government Geologist of Papua, Port Moresby, Papua.

In this report a summary is given of present knowledge of the geology of British and part of the lately German portions of New Guinea, and the tectonic relations of these to surrounding land-masses, the author having been Government Geologist of the region for the past ten years. The region is of especial tectonic and stratigraphic interest, because of its relationship to the Asiatic systems on the one hand and those of Australasia on the other. On an ancient complex of gneisses and schists invaded by a series of plutonic rocks, ranging from peridotite to granite, there rests a contorted series of less ancient quartzites, phyllites, and (presumably included here) crystalline limestones. These make up the greater part of the highlands of the south-east and the Louisiade islands beyond. A single record of the discovery of Devonian limestone with *Heliolites* exists. Jurassic ammonite-bearing shales pass up into Cretaceous beds, with a molluscan fauna. To the later Cretaceous period is assigned by the author (following earlier precedent) the *Alveolina* limestone, so widespread in the northern and western part of the island, which, however, Rutten has since declared to be Eocene. A long succession of Tertiary rocks are recorded, commencing with highly contorted siliceous and calcareous Eocene beds and Oligocene (?) radiolarian cherts, and the less disturbed Miocene lignite beds and limestones and Upper Miocene oil-bearing sands and marls. Varied Pliocene beds with much volcanic detritus and lavas, recent volcanic rocks, delta-deposits, and raised reefs make up the chief formations. Besides the middle Tertiary folding suggested by the above, there are explicitly described a great series of very late fractures and block-faulting movements, to which the relief of the present main ranges is very largely due, and the author points out also the huge amount of available energy (10,000,000 horse-power in British New Guinea alone) that could be readily obtained from the streams draining these mountains. In an inserted slip the author mentions the fact that he is forced to work over a thousand miles from a good geological library, and he desires to exchange this report for other published matter with whomsoever may desire it.

W. N. B.

GEOLOGIE IN TABELLEN. By Dr. K. ANDRÉE, Königsberg. In 3 parts, pp. xv+228. Berlin, Borntraeger, 1922. Price 8*s*.

ALL geologists will agree with the author's remark in the preface as to the great value of tables and diagrams in the teaching of their subject. The publication under review consists, with the exception of a brief introduction of 26 pages, entirely of tabular matter, covering almost every possible phase of geology and a considerable field of mineralogy. These tables are primarily divided into two chief groups, called general geology, and palæogeography and earth-history, respectively. The first class includes physical geology, mineralogy, and petrology, while the second deals with palæontology and stratigraphy. Both categories are interpreted in a liberal sense, and contain a good deal of matter not usually to be found in geological textbooks.

Many of the sections are of remarkable interest, and should be of the greatest use to British teachers and workers. We would call special attention to a summary of the geotectonic units of Europe, which contains a lot of material otherwise very difficult to extract from the voluminous writings of Continental geologists. With so much that is useful and up to date, we regret to find that the author still retains the double classification of the igneous rocks into "older" and "younger" series, perpetuating a system long discarded in England and America. Strange to say, also, we can find no sign of any recognition of the alkaline and calc-alkaline suites, and the table of rocks indicates that all syenites and trachytes have a higher silica-percentage than all diorites and andesites, which is certainly not the case. The petrographical classification can only be described as out of date and reactionary. This, however, is by no means an isolated example of this point of view among European writers. Some of the stratigraphical nomenclature, also, is by no means abreast of the times. Thus the Silurian still includes the Ordovician, although this name is given as equivalent to Lower Silurian, and the "Bala or Caradoc" includes the Ashghill (*sic*).

In spite of these blemishes, and the exclusively German bibliography, the book can be strongly recommended to advanced students as a useful compendium of many not easily accessible facts.

REPORTS AND PROCEEDINGS.

EDINBURGH GEOLOGICAL SOCIETY.

21*st February*, 1923.—Mr. T. Cuthbert Day, F.C.S., F.R.S.E., President, in the chair.

"The Hercynian Overthrust in the Belgian Coalfields." By Dr. John Horne, F.R.S.

One of the attractive features of the International Geological Congress held in Belgium in 1922 was the prominence given to the discussion of the Hercynian movements at the close of Carboniferous

time, combined with the opportunity of examining the evidence in the field connected with the great Hercynian overthrust in the Belgian coalfield. This narrow coalfield, with its rich coal seams, extending from Mons eastwards by Charleroi and Namur to beyond Liége, presented remarkable features, due to tangential pressure from the south. The Belgian geologists had worked out in detail the subdivisions of the Devonian and Carboniferous systems, which had been profoundly affected by these movements. The classification and distribution of the marine phases of the Devonian formation and of the Carboniferous limestone series which underlay the Coal-measures were described. It was shown that these rocks were thrown into sharp folds along a broad belt of country south of the main coalfield. In the coalfield itself the tangential pressure against the stable block formed by the Brabant arch culminated in a great reversed fault or overthrust, whereby the older Devonian strata were made to override the Coal-measures. Thus it had arisen that bores and pits had reached workable coals after passing through Devonian rocks—the equivalents of the Scottish Old Red Sandstone. The complicated structures in advance of the great overthrust, involving zigzag folding and the repetition of the coal seams by reversed faults, were illustrated. Reference was made to the researches of Fourmarier, of Liége, in connexion with the Theux *massif* north of Spa, which was now known as the " Theux Window ". In that area a small patch of Coal-measures had been laid bare by the denudation of the thrust Devonian strata which originally covered it. As this locality lay several kilometres south of the Liége coalfield, this interpretation implied a great extension southwards of Carboniferous beds beneath the transported Devonian materials. It further suggested that the broad belt of folded strata in the Dinant syncline had been moved northwards along the plane of the great overthrust. Reference was also made to Marcel Bertrand's application of the structures proved in the Franco-Belgian coalfield to the interpretation of the Glarus region in Switzerland. His paper, published in 1884, paved the way for the remarkable development of modern Alpine tectonics by Schardt, Lugeon, Termier, and other investigators.

7th March, 1923.

" Glacial Phenomena in the District of Galashiels." By R. J. A. Eckford and W. Manson, H.M. Geological Survey.

The dry channels and gravel terraces dealt with in this paper were formed during the later stages of the retreat of the ice sheet, when the main valleys were occupied by shrinking glaciers. The dry channels seen at Bluecairn and Threepwood appear to have been cut at successive stages by overflow waters from a lake held up in the Threepwood area by a mass of ice that lay in the lower tracts of the valley of the Allan Water. The overflow course leading into

the Leader Water breaches the ridge at Bluecairn and occurs at a height of 827 feet. A further retreat of the ice offered a lower point of escape for the impounded waters, and led into the Allan Water. This disused channel is seen near Threepwood. The withdrawal of the ice from the region on the northern side of the lake ultimately allowed the drainage to be by the Lauder Burn. The rugged waterworn appearance of the upper reaches of the Lauder gorge suggests that it has been greatly deepened by powerful currents.

A deep dry channel occurs at Knowes Dean on the divide between the Gala and Caddon Waters. This also appears to have been cut by an overflow from a sheet of water held up by a mass of ice in the level Caddon Valley.

The fluvio-glacial terraces of the Middle Tweed Valley are found in the wider reaches to be as much as 50 feet above the stream and 100 feet in the constricted portions. The materials composing these terraces are gravels derived largely from the erosion of boulder clay, and the overlapping arrangement of the stones in some sections is typical of that produced by water currents.

The esker seen at Holylee marks the position of a tunnel near the front of the Tweed glacier, and the fan of gravel into which the esker merges was formed of the gravelly material driven through this tunnel by powerful currents of water.

CORRESPONDENCE.

INSELBERGE.

Sir,—In Mr. Bain's interesting paper on "Inselberge" (pp. 97–101) a misprint of the date for the seventh volume of *Deutsch-Ost-Afrika*, which is 1900 and not 1910, obscures the fact that the term was practically due to Bornhardt (op. cit., pp. 22, 27–31, 34, etc.). Would you allow me to renew the objection advanced in "The Rift Valleys and Geology of East Africa", 1921, p. 35, as to the adoption of the term in British literature. I have no prejudice against German terms, except when, as in this case, a foreign word seems unnecessary. If a German name is to be used, then, according to the theory of the origin of these masses adopted by Mr. Bain, the older term "Rumpfberg" would be more suitable, as "Inselberg" would seem more appropriate for peaks isolated in water or in a sheet of alluvium. "Tor," which is applied not only to pinnacles but to isolated hills, such as Mam Tor and Kilmarth Tor, seems the well-established English term for hills of this type.—Yours faithfully,

J. W. Gregory.

University of Glasgow.
13th March, 1923.